Thesis for doctoral degree (Ph.D.) 2021

Hips don't lie – the use of benchmarking and register data to assess the performance of orthopaedic care

Fanny Goude

Karolinska Institutet

Thesis for doctoral degree (Ph.D.) 2021

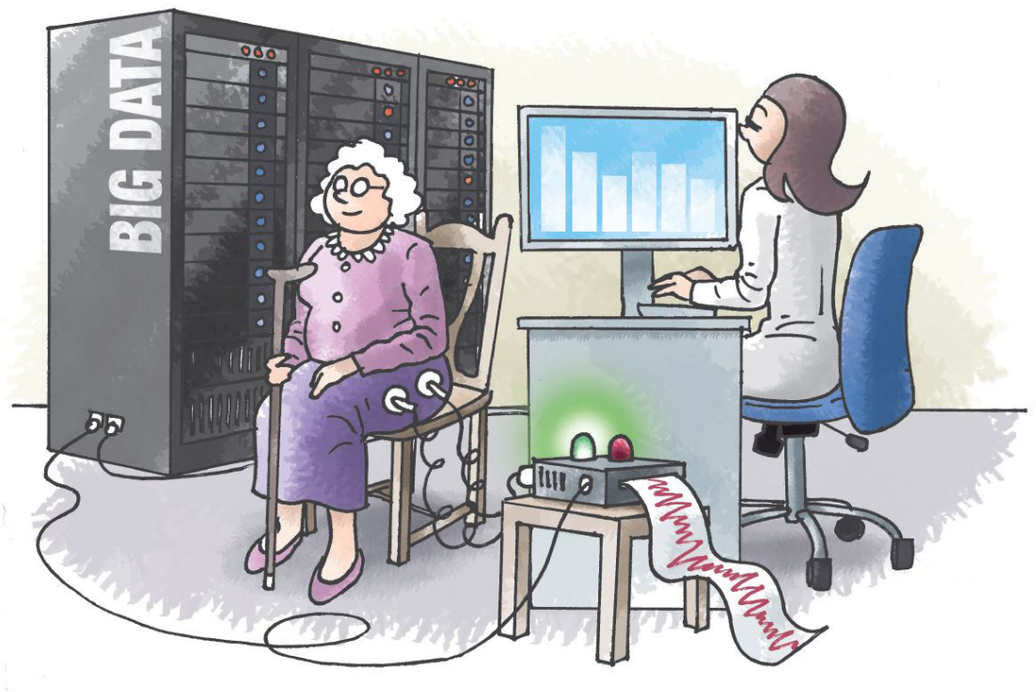
Hips don't lie – the use of benchmarking and register data to assess the performance of orthopaedic care

Fanny Goude

Karolinska Institutet

Thesis for doctoral degree (Ph.D.)
2021

Hips don't lie – the use of benchmarking and register data to assess the performance of orthopaedic care



Fanny Goude

Karolinska Institutet

From DEPARTMENT OF LEARNING, INFORMATICS, MANAGEMENT AND ETHICS
Karolinska Institutet, Stockholm, Sweden

HIPS DON'T LIE –

THE USE OF BENCHMARKING AND REGISTER DATA TO ASSESS THE PERFORMANCE OF ORTHOPAEDIC CARE

Fanny Goude

Karolinska Institutet

Stockholm 2021

All previously published papers were reproduced with permission from the publisher.
Published by Karolinska Institutet.
Printed by Universitetsservice US-AB, 2021

ISBN 978-91-8016-236-4
Cover illustration: Pontus Andersson, Pontus Art Production

Hips don’t lie – the use of benchmarking and register data to assess the performance of orthopaedic care

THESIS FOR DOCTORAL DEGREE (Ph.D.)

By

Fanny Goude

The thesis will be defended in public at Karolinska Institutet, Samuelssonsalen, Tomtebodavägen 6, Stockholm, May 28th, 2021 at 9:30 AM.

Principal Supervisor:
Professor Clas Rehnberg
Karolinska Institutet
Department of Learning, Informatics, Management and Ethics
Medical Management Centre

Co-supervisor:
Professor, Director Sverre A.C. Kittelsen
University of Oslo
Department of Health Management and Health Economics

Ragnar Frisch Centre for Economic Research

Opponent:
Research Professor Kamrul Islam
NORCE Norwegian Research Centre
Department of Social Sciences
Health Services and Health Economics

University of Bergen
Department of Economics

Examination Board:
Professor Emeritus Gunnar Németh
Karolinska Institutet
Department of Molecular Medicine and Surgery
Unit of Orthopaedics

Associate Professor Anna Häger Glenngård
Lund University
School of Economics and Management
Department of Business Administration

Associate Professor Carl Bonander
University of Gothenburg
Sahlgrenska Academy
School of Public Health and Community Medicine

Till min familj

POPULÄRVETENSKAPLIG SAMMANFATTNING

Dagens hälso- och sjukvårdssystem står inför stora utmaningar. Dessa inkluderar ett ökat behov av sjukvård från en åldrande och växande befolkning, variationer i vårdkvalitet mellan olika vårdgivare, överdriven eller onödig användning av sjukvård samt ökade sjukvårdskostnader. Det är därför viktigt att åstadkomma förbättringar inom vården och se till att de begränsade resurserna som finns tillgängliga används på bästa möjliga sätt.

För att stödja organisationer och vårdgivare i deras förbättringsarbete kommer benchmarking, det vill säga systematiska jämförelser, väl till användning. Benchmarking är en process där verksamheter utvärderas i förhållande till varandra med avseende på olika resultatmått och ger insikt i bästa praxis. På så sätt kan verksamheterna identifiera eventuella förbättringsområden. I ett annat avseende är benchmarking också användbart för att utvärdera effekterna av hälso- och sjukvårdsreformer.

Syftet med den här avhandlingen var att visa hur benchmarking tillsammans med ”big data” från patient- och befolkningsregister kan tillämpas för att mäta resultat utifrån olika perspektiv och nivåer inom hälso- och sjukvården. Bland annat ges inblick i hur benchmarking kan användas för att identifiera och analysera variationer i resultat inom ortopedisk vård. Här jämförs dels vårdtid och dödlighet för patienter med höftfrakturer mellan och inom sju europeiska länder, dels produktivitetsutvecklingen för höftprotesoperationer hos ortopedavdelningar inom Sverige. I båda jämförelserna påvisas betydande variationer i vården, vilket indikerar att det finns utrymme för förbättringar och att beslutsfattare bör ta lärdom av bästa praxis.

Vidare ges insyn i hur benchmarking kan användas i syfte att utvärdera sjukvårdsreformer. Här studeras en uppmärksammad vårdvalsreform för höftprotesoperationer där konkurrens och ekonomiska incitament introducerades i Region Stockholm. Resultaten tyder på att reformen har medfört en kvalitetsförbättring vad gäller komplikationer efter operation. Däremot minskade inte vårdtiden i samband med operation i samma takt som tidigare och patientrapporterade kvalitetsmått lämnades oförändrade. Dessa resultat bidrar till den allmänna kunskapen om effekterna av konkurrens och ekonomiska incitament och kan användas för att informera framtida beslutsfattande.

Framtida perspektiv bör fokusera på hur informationen som erhålls med hjälp av benchmarking kan och bör användas i praktiken för att förändra organisationers och vårdgivares beteenden i syfte att förbättra vården.

ABSTRACT

Background: Today's healthcare systems face challenges involving rising need and demand for healthcare as well as concerns about cost containment, misuse of medical services and unwarranted variations in medical practices. Given the stretched budgets for healthcare, there is a need to improve healthcare performance and to make competent use of limited resources.

To support organisations in improving performance, benchmarking is a valuable tool for several reasons. First, it is an effective substitute for competition in the public sector. Second, through benchmarking, performance differences between organisations in various measures are revealed, and for those performing less optimally, possible improvement areas may be discovered. Third, benchmarking is useful for evaluating the impact of healthcare reforms on performance. Coupled with big data from patient registers and other administrative registers, benchmarking thus can offer opportunities for finding ideal structures in the provision and financing of healthcare.

Aim: The overall aim of this thesis was to show how benchmarking can be applied to assess healthcare performance with the use of register data.

Methods: The four studies included in the thesis were based on two comprehensive patient-level datasets, with data obtained from multiple registers. Study I applied international benchmarking, with the performance for the surgical treatment of hip fractures being assessed between and within seven European countries. Regression analyses were used to explore associations between age- and sex-adjusted mortality rates and length of stay (LOS) and selected country- and region-level variables.

In Studies II–IV, a national perspective was considered in the assessment of the performance of elective hip replacement surgery in Sweden. In Study II, the orthopaedic departments' productivity development between 2005 and 2012 was measured by the Malmquist Productivity Indices. The indices were further decomposed into changes in efficiency and technology. In Studies III and IV, a quasi-experimental research design was applied to assess the effects of a healthcare reform involving competition and financial incentives introduced in the capital region in 2009. In both studies, difference-in-difference analysis was used to estimate the causal effects on LOS and various measures of subjective and objective quality. In Study III, the difference-in-difference analyses were also stratified by hospital type to examine whether the reform had heterogenous effects across hospital types. In Study IV, an entropy balancing algorithm was further applied to make the intervention and control groups comparable.

Findings: Study I revealed marked differences in age- and sex-adjusted LOS and mortality rates for hip fracture patients, across and within included countries. Variations were found to

be associated with the availability of national clinical guidelines, the share of males in the region and country-specific effects.

In Study II, differences in the development of productivity, efficiency and technology in the provision of hip replacement surgery across and within the orthopaedic departments were revealed. The overall results indicated a slight positive productivity development over the study period, which was primarily due to catch-up effects (improvements in efficiency), rather than changes in technology.

The findings from Study III indicated that the reform led to the LOS of the surgical admission not decreasing at the same rate as before, and to reduction of the adverse event rate within 90 days following surgery. These effects were driven mainly by university and central hospitals. Furthermore, the reform brought no changes in patient satisfaction with the outcome of the surgery (Study III and Study IV) or gains in various patient-reported outcome measures at one- and six-year follow-ups (Study IV).

Conclusions: The thesis has demonstrated how benchmarking can be applied to assess healthcare performance with the use of register data, with the four studies contributing with various perspectives and measurements at different levels of healthcare systems. First, the thesis has exemplified how performance measurement can be applied to identify and analyse performance gaps. Considerable variations in the performance of orthopaedic care between and within units of analysis were revealed at the departmental and international levels. This implies that there is room for improvement and that stakeholders should learn from best practices.

Second, the thesis has demonstrated how benchmarking can be useful in the assessment of healthcare reforms. The findings indicated that the studied reform reduced the adverse event rate, led to LOS not decreasing at the same rate as before and had no effect on patient-reported outcome measures. These findings contribute to the general knowledge about the effects of market elements and financial incentives and can be used to inform decisionmaking.

Future perspectives should focus on how this information can and should be used in practice to change organisations' behaviour and to improve healthcare performance.

Key words: performance, benchmarking, register data, quality, length of stay, mortality, patient-reported outcome measure, productivity development, hip fracture, total hip replacement, Europe, Sweden, competition, bundled payment, quasi-experiment

LIST OF SCIENTIFIC PAPERS

I. Medin, E., **Goude, F**., Melberg, H.O., Tediosi, F., Belicza, E., Peltola, M., EuroHOPE Study Group. European regional differences in all-cause mortality and length of stay for patients with hip fracture. *Health Economics*, 2015;24(Suppl 2):53-64.

II. **Goude, F**., Garellick, G., Kittelsen, S.A.C., Nemes, S., Rehnberg, C. The productivity development of total hip arthroplasty in Sweden: a multiple registry-based longitudinal study using the Malmquist Productivity Index. *BMJ Open*, 2019;9(9):e028722.

III. **Goude, F**., Garellick, G., Kittelsen, S.A.C., Malchau, H., Peltola, M., Rehnberg, C. The effects of patient choice and bundled payment on the performance of hip replacement surgery in Stockholm, Sweden – results from a quasi-experimental study. *Manuscript submitted*.

IV. **Goude, F**., Kittelsen, S.A.C., Malchau, H., Mohaddes, M., Rehnberg, C. The effects of competition and bundled payment on patient reported outcome measures after hip replacement surgery. *BMC Health Services Research*, 2021;21:387.

CONTENTS

LIST OF ABBREVIATIONS

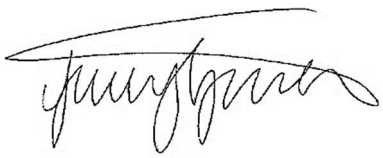
DiD	Difference-in-difference
DRG	Diagnosis-related group
EuroHOPE	European Health Care Outcomes, Performance and Efficiency
GDP	Gross domestic product
LOS	Length of stay
PROM	Patient-reported outcome measure
SHAR	Swedish Hip Arthroplasty Register
VAS	Visual analogue scale

PREFACE

I thought I would take the opportunity to briefly describe my academic background to give the reader a hint as to what perspective I have had in the pursuit of completing this PhD project. As a great fan of numbers, I started with mathematics, statistics and computer science which eventually led to a master's in economics. After that, I became a research assistant in the Health Economics and Policy research group at Karolinska Institutet and was immediately thrown into the EuroHOPE project (which the reader will learn more about later). Little did I know that this was the start of my research career. To complement my background in economics, I also took the opportunity to pursue a master's of medical science in health economics, policy and management at Karolinska Institutet. A while later, I took what felt like the natural step – and there I was, a PhD candidate.

If I benchmark my research performance today against what it was when I first started as a research assistant, I see how it has improved and what my achievements are. I have been guided by previous research and best practice, and learned about strengths and weaknesses, both my own and those of research. Looking back, I see that in a way, one could say that benchmarking has allowed me to adapt, grow and thrive through change in my research learning process. Of course, I have no register data to back me up, so you just have to take my word for it.

Enjoy the reading!



Fanny Goude
Stockholm, April 2021

1 INTRODUCTION

'By the adoption of the register, physicians and surgeons would obtain clearer insight into the comparative success of their hospital and private practice; and would be incited to a diligent investigation of the causes of such difference.' – Sir Thomas Percival, 1803

The improvements in health within the past century has been nothing short of remarkable. The incidence of illness and death has decreased significantly, in part because of medical advancements towards more efficient treatment and care. Populations are thus growing and getting older, which in turn results in increased need and demand for healthcare. The downside of this fundamentally positive development is increased healthcare costs (1-4).

Moreover, in addition to concerns about cost containment, there are indications of over- and undertreatment, as well as unwarranted variations in medical practices, suggesting that there is room for improvements (4). Given the stretched budgets for healthcare, there is thus an intense pressure on health systems to improve healthcare performance and to make competent use of limited resources (2, 3).

To support health systems in improving performance, benchmarking, i.e., systematic comparisons, is a valuable tool for several reasons. First, benchmarking is an effective substitute for competition in the public sector, which is a particularly attractive feature in healthcare markets, where market forces are largely absent due to uncertainty and information asymmetry (5). Second, through benchmarking, performance differences between healthcare organisations in various measures (e.g., quality and cost containment) are revealed, and for those performing less optimally, possible improvement areas may be discovered (6). Third, healthcare reforms are continuously being implemented, with the ultimate purpose of improving performance. Here, too, benchmarking can be useful to evaluate their effects on performance (7). In many ways, benchmarking thus offers opportunities to find ideal structures in the provision and financing of healthcare.

1.1 RATIONALE FOR THE THESIS

Performance benchmarking in healthcare has been applied since the 17th century; thus, this thesis is not the beginning. It is not an era of something new, of something unseen. However, given the challenges that health systems face today – increasing costs, misuse of medical services and wide variations in performance – the need for performance measurement and transparency is perhaps greater than ever.

Benchmarking is a continuous process, constantly in search of areas that can be improved. When combined with big data from patient registers and other administrative registers, it provides information and knowledge that can lead to scientific findings and sustained healthcare improvements.

This thesis has made use of such 'real world evidence' and gives insights into how benchmarking can be applied within various contexts. First, it provides comparisons at three levels: between countries, between regions and between departments. Second, it demonstrates how performance measurement can be applied to both identify and analyse performance gaps, as well as to evaluate healthcare reforms. Underlying all of these efforts was the goal to inform decisionmaking on the part of various stakeholders (e.g., clinicians, managers and governments), to ultimately achieve improved healthcare performance.

1.2 SETTING THE SCENE

The studies in this thesis assessed healthcare performance in two settings (illustrated in Figure 1), with different aspects and applications of performance benchmarking being demonstrated. In both settings, a disease-based approach was adopted in the field of orthopaedic care. While the first setting, Setting 1, focused on hip fractures, which are a major cause of morbidity and mortality and are associated with high healthcare costs worldwide, the second setting, Setting 2, focused on elective hip replacement surgery due to osteoarthritis, another common condition. Both conditions have been subject to policy interventions aiming to improve healthcare performance, such as fast-track for hip fractures and patient choice for elective hip replacement surgery in Sweden. Given this, and the increasing incidence of hip fractures and elective hip replacement surgeries, both conditions are relevant for performance measurement.

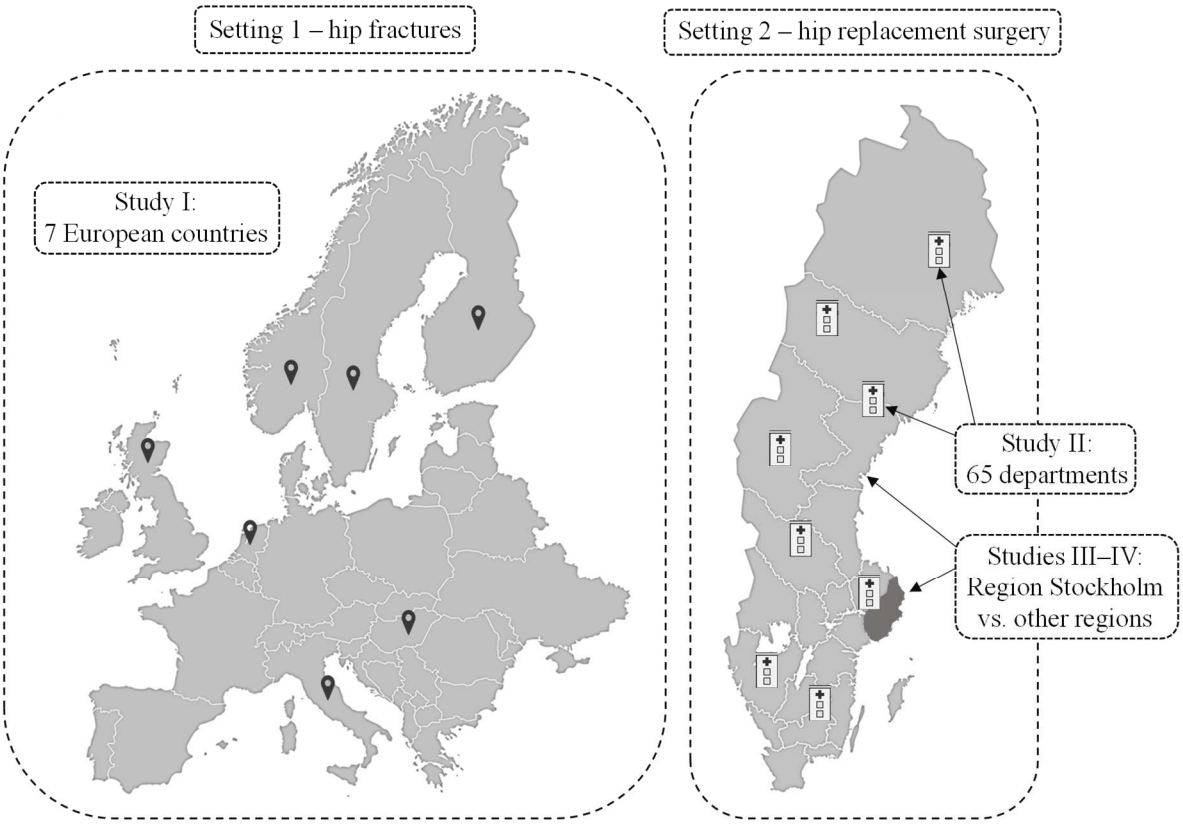


Figure 1. Illustrative overview of the studies in the thesis.

Setting 1, represented in Study I, contributed with insights into international benchmarking, where the performance for the surgical treatment of hip fractures was assessed between and within seven European countries. The selection of relevant performance indicators was based mainly on data availability across participating countries. The empirical data for this setting was provided by the project entitled European Health Care Outcomes, Performance and Efficiency (EuroHOPE), which was funded by the European Union's Seventh Framework Programme.

In Setting 2 (represented in Studies II–IV), the performance of elective hip replacement surgery in Sweden was considered. Thus, a national perspective was applied. In Study II, the units of comparison were orthopaedic departments, whereas in Study III and Study IV, the measurement focus was shifted to the regions, to evaluate the effects of a healthcare reform implemented in the capital region. In this setting, rich empirical data were provided by the Swedish Hip Arthroplasty Register (SHAR) and other administrative registers, which enabled a multidimensional assessment of performance.

1.3 DEFINITIONS OF CENTRAL CONCEPTS

A number of concepts are central to this thesis; their definitions and meanings are elucidated below.

Benchmarking

The concept of *benchmarking* has been defined by several authors and organisations, with a common theme of identifying and implementing best practices. Basically, benchmarking is a process where the performance of various organisations is compared and differences are revealed, with the intention of enabling organisations to improve their own performance on the market (6). Throughout the thesis, benchmarking is used synonymously with the terms performance measurement and (systematic) comparisons.

Performance

The concept of healthcare *performance* is complex and multidimensional, and incorporates cornerstones such as equity, efficiency and several dimensions of quality of care (8). 'Performance' is the degree to which health systems or organisations are fulfilling these dimensions (3).

In this thesis, performance has been assessed through various measures of quality (Studies I, III and IV), resource use (Studies I and III) and productivity (Study II), the definitions of which follow below.

Quality

Quality is also a complex concept with multiple dimensions. A broadly used definition of quality in healthcare is that from the Institute of Medicine committee: *'quality of care is the*

degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge' (9). Although outcome measures are highlighted in the definition, it also considers the connection between processes of healthcare and outcomes (9).

Health outcomes refer to changes in a patient's health condition as a result of received healthcare. However, due to difficulties in measuring such changes, proxy indicators are often used instead. These include measures of health status (e.g., indicators on avoidable hospitalisations and mortality) and process of care measures (for example, indicators reflecting utilisation, which are assumed to be related to outcomes, such as screening rates) (3).

In the thesis, a number of indicators were measured to capture various aspects of both subjective and objective quality, including measures directly capturing outcomes (patient-reported outcome measures (PROMs) of gains in health status and pain level in Study IV) and proxies of outcomes (mortality in Study I, adverse events in Study III and patient satisfaction in Study III and Study IV).

Resource use

A frequently used indicator of *resource use* is length of stay (LOS), which may be viewed as an indicator of efficiency and a surrogate measure for costs. In that regard, providers with shorter LOS are considered to be efficient in resource use, while providers with longer LOS are inefficient (10).

In both Study I and Study III, resource use was analysed in terms of LOS.

Productivity

Although the terms *productivity* and efficiency – both widely used concepts in economics – are closely related, they do differ. They are sometimes used interchangeably, but in this thesis, they are differentiated when necessary. While productivity is a ratio that can be written in real units, such as patients per nurse, efficiency is always defined relative to the best possible, e.g., as 95% or 100% efficient.

In Study II, performance was evaluated in terms of productivity change, which was further decomposed into changes in efficiency and changes in technology (these concepts are defined in the study).

Register data

Register data refer to routinely collected information on patients or population groups, that is stored and administered in a register format (11). For example, there are patient registers which contain data on patients and their healthcare events, and population registers which include detailed information on, e.g., demographics. In Sweden, there are also several national quality registers which contain data on medical interventions and outcomes following treatment for specific patient groups (12). Furthermore, in Sweden (and many other countries), individuals

are identifiable in the registers, which makes it possible to track them at the individual level through many different data sources.

We find many names for the things we love; hence, I have used many different terms for register data in this thesis, including – but not limited to – big data, real world data and administrative data.

2 AIM

The overall research aim of the thesis was to show how benchmarking can be applied to assess healthcare performance through the use of register data. The applications were demonstrated in the orthopaedic care of patients with hip osteoarthritis and hip fracture. The thesis includes four empirical studies with the following specific aims:

- Study I: To assess associations between selected country- and region-level factors and age- and sex-adjusted mortality rates and LOS following surgical treatment of hip fractures in seven European countries.

- Study II: To analyse the productivity development, including changes in efficiency and technology, in the provision of hip replacement surgery in Sweden between 2005 and 2012.

- Study III: To assess the effects of a policy reform involving competition and bundled payment on the performance of hip replacement surgery measured as LOS of surgical admission, adverse event rate and patient satisfaction with the outcome of the surgery.

- Study IV: To examine the effects of competition and bundled payment on the perceived quality of elective hip replacement surgery as captured by PROMs of health gain, pain reduction and patient satisfaction with the outcome of the surgery.

3 BACKGROUND

The improvements in population health during the past century have been remarkable. Many of the main reasons for these improvements lie outside the field of healthcare, such as improvements in water and food supply, sanitation and control of disease vectors. Economic growth has also contributed through better nutrition and education. The health status improvements are most apparent in declines in mortality and steady increases in life expectancy (1). Nowadays, there are several countries with populations with an expected lifespan of 80 years, in contrast to the situation a hundred years ago, when almost no populations had a life expectancy of more than 50 years (13). Moreover, pharmaceutical developments such as vaccines and antibiotics have contributed to the significant decreases in the incidence of illness and death (1). While populations are growing and aging thanks to these improvements, and some disease progressions are being decelerated because of medical advancements towards more efficient treatment and care, disease profiles are changing (such as the rise in non-communicable diseases), which in turn increases healthcare utilisation (2-4).

The downside of this fundamentally positive development is greater healthcare costs due to increased and changed need and demand for healthcare (2-4). Adding to that are the technological advances (e.g., diagnostic, surgical, therapeutic and imaging) in combination with new drugs, tests and devices in standard medical practice, which further drive expenditures (4). Furthermore, there is evidence that medicines, tests and healthcare services are misused (provision of appropriate care, but in a way that can lead to avoidable complications), overused (unnecessary provision of health services) and underused (absence of necessary provision of health services) (4, 14). Additionally, there are wide variations in medical practices which cannot be explained by the characteristics of individuals or health status of patients, i.e., unwarranted variations. These factors also drive growing healthcare costs (4). For instance, according to Hicks and Makary (15), a report from the Institute of Medicine in 2012 concluded that up to a third of all US healthcare costs might be redundant and might not improve health outcomes.

Consequently, there is an intense pressure on health systems to improve healthcare performance and to make competent use of limited resources (2, 3). To support organisations and systems in improving performance, benchmarking of relevant performance measures is valuable (3, 16-18). Benchmarking can be summarised as a tool to offer organisations guidance in feasible performance levels and an understanding of strengths and weaknesses on the market, to promote changes and innovations as well as to deliver improvements in performance. Additional benefits of benchmarking are its cost-effectiveness and time efficiency (6). Moreover, benchmarking may be beneficial in the evaluation of effects of healthcare reforms (7). In the public sector, benchmarking is further an effective substitute for competition, which is a particularly attractive feature in healthcare markets where market forces are largely absent due to uncertainty and information asymmetry (5).

3.1 THEORETICAL ASPECTS

The theory underpinning benchmarking hinges upon comparison of performance, identification of performance gaps and changes in the management process (6). In their pursuit of a benchmarking theory for the public sector, van Helden and Tillema (5) used elements from both economic and institutional reasoning. The latter derives from neo-institutional and resource dependence theories, and provides insight into motivations and processes that trigger organisations' responses to institutional pressures in the public sector (5). Nevertheless, as this thesis is placed in the field of health economics, the following discussion on theoretical aspects will be delimited to economic reasoning, with the healthcare market as point of departure. Related empirical literature will also be highlighted.

3.1.1 The market for healthcare

Healthcare markets are characterised by several features distinguishing them from 'perfect markets', including extensive government regulations, imperfect information, differentiated products and lack of price transparency (19-21). These imperfections are mainly derived from the high level of uncertainty and the asymmetry of information that are intrinsic to healthcare (19, 21), as recognised by Arrow in the early 1960s (22). The institutional response to uncertainty has been various types of third-party payer arrangements, such as national health service (tax-funded healthcare), social insurance and voluntary insurance (23).

To alleviate market failures caused by these imperfections, market-oriented elements such as regulated competition, financial incentives and performance measurements are being introduced to the healthcare sector, with the ultimate goal to improve performance.

3.1.2 Benchmarking

Based on economic reasoning, in the presence of market forces, consumers can choose a supplier in accordance with their own preferences. As the survival of poor performing suppliers who face low demand is thus threatened, they are motivated to improve their performance (5). However, in the absence of such forces, benchmarking has been advocated as a substitute for the competitive mechanism in the public sector. It is argued that since benchmarking enables consumers (patients, third-party payers, et cetera) to compare healthcare providers' relative performance, the providers are incentivised to improve. In the case of unwarranted performance gaps, poorly performing providers feel pressured to improve (5, 24-26).

3.1.3 Competition and financial incentives

With inspiration from economic theory, competition and financial incentives are being introduced to the market with the aim of correcting for market imperfections and improving performance. However, when third-party payers are involved, such elements may themselves introduce new problems, including risk selection and moral hazard, which need to be considered when designing market-based reforms (19, 21, 23, 27, 28).

Previously, competition in healthcare was confined to the US, but in the last few decades, competition has increasingly been introduced into European healthcare systems on either the provider or the insurer side of the market (27, 29). In the Northern European countries, provider competition is driven by patient choice in both hospital care and primary care. As the price for treatment is usually fixed for all providers, there is no price competition. Instead, providers compete in terms of quality in systems where the money follows the patient. In theory, by offering patients a choice, providers are incentivised to improve their quality of care and efficiency. In addition, patient choice is advocated as a means of improving responsiveness and empowering patients (28-32). Moreover, private providers may enter the market to some extent; however, they typically need authorisation from a public authority or insurer (30).

Various prospective payment and reimbursement schemes with different mechanisms of financial incentives have furthermore been developed to improve provider performance. If these are optimally designed and used under appropriate conditions, problems of risk selection may be avoided. Examples of payment models include pay-for-performance schemes, in which provider payments are linked to specific performance targets, and bundled payments, where providers are given a lump sum for a defined episode of care (33-36).

The body of empirical work on the effects of market-oriented reforms in healthcare markets is growing, but the evidence is mixed and unpredictable. Because of the complexity of reforms, it is challenging to disentangle the effects of competition from accompanying changes in payment mechanisms in some studies (37). Furthermore, the impact of competition is subject to contextual settings and important market characteristics, including policy design, whether pricing is centralised, availability of information and who makes the choice (37, 38). While there is limited evidence from the Swedish health system (39), studies from the health systems in the US and UK have found that competition, as theory would predict, improves quality of care (29, 40). Nevertheless, the overall evidence suggests that choice and competition have limited desired effects on efficiency and quality (37, 41, 42).

The evidence-based effects of financial incentives are more difficult to recapitulate due to the large variety of payment models with different mechanisms of financial incentives, in addition to contextual settings. Reviews within the field summarise the literature as limited (but growing) and fragmented, with results ranging from negative (unintended) to positive effects. This further limits generalisability and the results may be subject to methodological weaknesses. It is therefore difficult to draw any general conclusions on the effects of financial incentives (43-46).

3.1.4 The link between measurement and improvement

The measurement of performance is necessary, but not sufficient, for improvement. Nevertheless, there are many possible mechanisms connecting the process of measurement to the process of improvement. Traditional mechanisms include regulation, feedback based on performance measurement, targets and marketplace competition. Two of the most widely

advocated strategies to promote improvement are public reporting of performance and pay-for-performance programmes (47).

In their paper, Berwick et al. (48) discuss two pathways serving as stimulus for performance improvement through the public disclosure of data. The first pathway relies on the actions of consumers to become better informed and choose providers of higher quality. Examples of this pathway include selection on the part of the individual patient, selective referral by practitioners and selective contracting by third-party payers. The second pathway is about change, where the information is used to identify areas of poor performance to help providers focus on what can be improved (48). While public reporting has been found to have little effect on the selection pathway, there is increasing evidence that the change pathway does stimulate improvement activities in hospitals. Public reporting also enhances general accountability to funders and other stakeholders, thereby stimulating improved performance (18). On the other hand, public reporting may result in adverse unintended consequences, such as avoidance of high-risk patients (49).

Financial incentives linked to performance are increasingly being employed to improve performance by rewarding excellence. The effects of such pay-for-performance programmes vary depending on their design, including which aspects of performance are targeted, how the targets are set, how strong the connection between achievement and reward (versus penalty) is, the extent of the incentives and whether incentives are offered at the individual or group level. The predicted impact of these dimensions on performance, based on theory, has been further discussed by Conrad elsewhere (50). As described above (albeit there focused on financial incentives in general, not on pay-for-performance programmes), it is difficult to summarise the effects of different performance incentive schemes, given their wide range. As in the case of public reporting of data, performance incentives may potentially lead to unintended responses, such as cream skimming and miscoding of diagnoses (50).

3.2 PERFORMANCE MEASUREMENT IN HEALTHCARE

The most important objective of health systems is to improve the health of the patients and populations they serve. Here, ‘health’ relates to both health outcomes following treatment and broader public health. Other key objectives of health systems are responsiveness to the population’s expectations and preferences, provision of financial protection against cost of ill health and efficient utilisation of resources. Moreover, health systems are complex and involve many stakeholders (including patients, healthcare providers, managers, governments, and citizens). The measurement of performance in healthcare seeks to monitor, assess and communicate the degree to which the objectives are met, in order to inform the decisionmaking of the various stakeholders (18, 51).

3.2.1 A model of performance measurement

At an elementary level, the process of performance measurement can be described as in Figure 2, with the healthcare system for which performance improvements are desired depicted to the left. In the first stage of the process, data are collected and performance is measured. In the second stage, the collected data are analysed and interpreted, taking background influences into account. If the analysed data indicate a need for change, the final stage involves some sort of action to change the behaviour of the organisation. This action varies with the organisations concerned, but may for instance involve informing the choices of consumers or third-party payers (3, 24, 52).

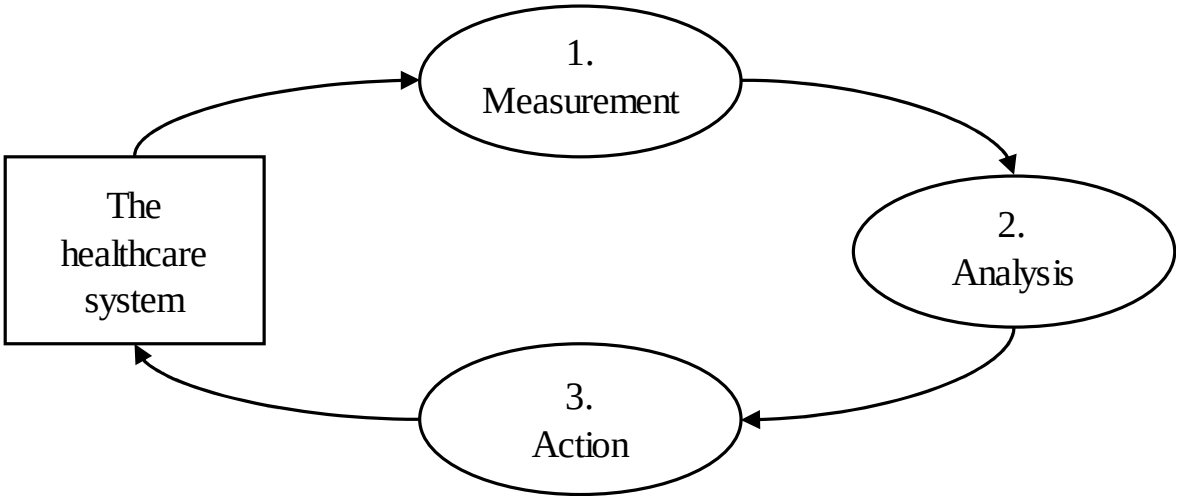


Figure 2. A model of the performance measurement process. Adopted from Nutley and Smith, 1998 (52).

3.2.2 A journey into history

There is evidence that performance measurement in the healthcare sector dates back as early as to the 17th century, when mortality in hospitals was compared (53). In 1754, the Pennsylvania Hospital collected data on patient outcomes, tabulated by diagnostic groups (54, 55). Efforts at performance measurement to improve care continued to occur during the 19th century, with Sir Thomas Percival – a British physician best known for his work on a medical ethics code (56) – promoting the idea of tracking patient outcomes using a hospital register (57, 58), and Florence Nightingale, 'The Lady With the Lamp', collecting hospital data on mortality and infection rates in England during the Crimean War (54).

However, it was not until the early 1900s that systematic healthcare performance measurement began to emerge as a tool to assess and improve healthcare, when Dr Ernest Amory Codman, a surgeon at Massachusetts General Hospital, proposed the 'end result system' (59, 60). The idea behind this system was to collect data on outcomes of various patient treatments, identify the best and worst surgeons, and make this information publicly available to guide patients in their choice of physicians and hospitals. He believed that by understanding the results following patient care, physicians could take action to change their clinical practices in order to improve the care of future patients. Transparency of results would also enable physicians to learn from each other's mistakes. Codman was rather radical and when he presented the 'end result

system' during a meeting of the local medical society, he unveiled a cartoon depicting greedy surgeons concerned only with reimbursements associated with surgery, not with the outcomes following the surgery (Figure 3). Needless to say, this was not well-received and Codman resigned and opened his own hospital, which however was closed shortly thereafter. Still, the 'end result system' was soon incorporated by the American College of Surgeons, an association established to improve the quality of care for patients (15, 54, 55, 61).

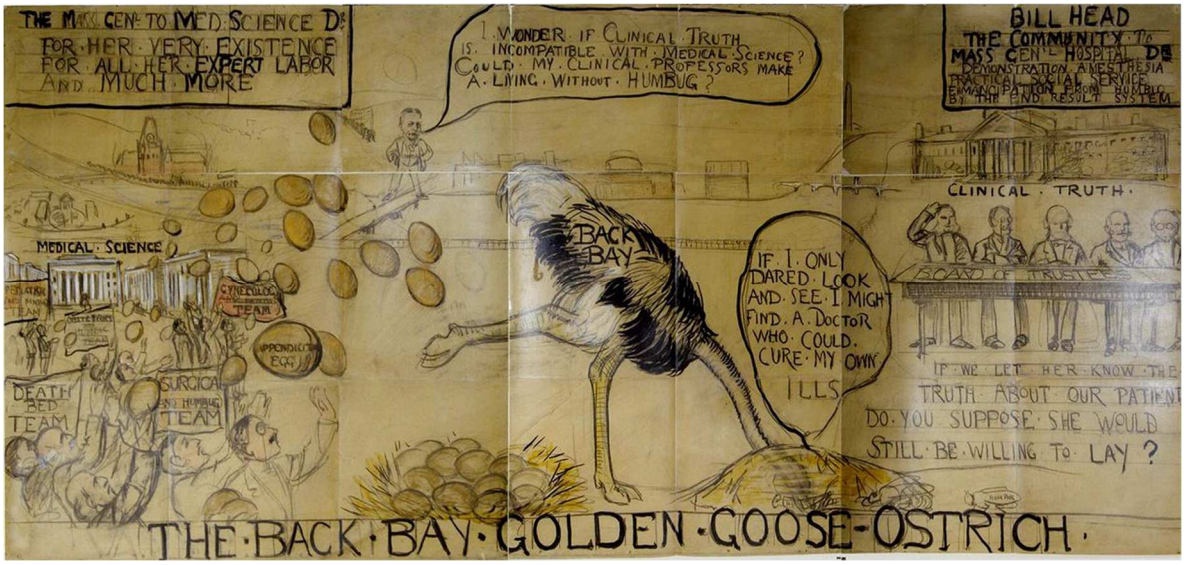


Figure 3. Codman's famous cartoon – 'The Back Bay golden goose ostrich'. The cartoon depicts an ostrich (representing the patients/public, labelled with reference to an area in Boston known as the Back Bay) with its head buried in the sand and laying golden eggs, and highlights how the fee-for-services system encouraged overtreatment and made physicians rich through poor quality care (15, 61). Held by Boston Medical Library in the Francis A. Countway Library of Medicine. Public Domain.

A century later, performance measurements are still supported by the ideas and principles of Codman (54). In more recent history, there are several examples of international performance benchmarking projects (53, 62, 63). For instance, the Organisation for Economic Co-operation and Development has performed benchmarking of healthcare systems since the 1980s (63). This work has been developed into a comprehensive database containing more than 1,200 indicators on different aspects of health systems in the member states (64). A similar example is the work carried out by the World Health Organization, in which the overall performance of health systems was assessed and compared between member states. The results were published in the widely known World Health Report 2000 (51).

Furthermore, national performance measurement frameworks have been developed in many countries. In Sweden, examples of such frameworks are the national quality registers which systematically collect data on various patient groups. Initiated by the medical profession, the first quality register was established in the 1970s. Nowadays, there are over a hundred quality registers in Sweden, with the ultimate purpose to be used for continuous improvement work in healthcare by comparing the performance of healthcare providers (65). The quality registers have also been crucial in making 'Regional Comparisons' possible, another example of a performance measurement framework in Sweden. The 'Regional Comparisons' concept was developed by the National Board of Health and Welfare together with the Swedish Association

of Local Authorities and Regions and has been used since 2006 to compare the quality of healthcare and social services in Sweden (66, 67).

3.2.3 Methodological aspects

Benchmarking is a continuous process and a seemingly simple endeavour with many benefits. However, there are some challenges and potential risks involved with the benchmarking process in the healthcare environment. One of the main issues concerns the comparison of non-comparable units. As each healthcare provider or organisation differs, for example in terms of mission, environment and available technology, benchmarking could be misleading if units are benchmarked against others outside the specific area of comparison. For instance, in the absence of proper risk adjustments which take account of healthcare providers' different compositions of patients, adopting what seem to be the best practice standards into one's own organisation might result in adopting standards from an inferior organisation (6, 54, 63).

Another challenge relates to the measurement focus and the selection of performance indicators. There are several dimensions and subcategories of health system performance, and depending on the specific objective of a comparison, the selected indicators may focus on the measurement of, for example, health outcomes, responsiveness or efficiency. This is also connected to the availability and quality of the data, which often vary across different settings, and may thus be an issue (54, 63). Campbell and colleagues (68) raise a few important points related to developing or applying indicators, including which stakeholder perspective(s) the indicators are intended to reflect and what aspects of healthcare should be measured. Further, although it may never be possible to develop an error-free indicator, indicators should in so far as possible exhibit the features of acceptability, feasibility, reliability, sensitivity to change and validity (68).

Other methodological aspects relate to the levels of comparison and assessment. In the field of benchmarking in healthcare, comparisons can be made at either an international level, i.e., between healthcare systems, or at the country level, i.e., within a given system. Furthermore, the comparisons can be based on data derived from different levels or strata within the healthcare system, such as individual practitioners, primary care centres, pharmacies, hospitals, districts and regions, the disease or condition level, or the country level. Also, comparisons can be made at one time point or over time and within or between units (63).

3.3 THESIS BUILDING BLOCKS

The thesis was based on two large-scale projects: the EuroHOPE project and a coordination project initiated by SHAR, which were previously referred to as Settings 1 and 2, respectively (Figure 1). These projects are briefly described below.

3.3.1 The EuroHOPE project

The EuroHOPE research project was launched in 2010. The project was a collaboration between seven European countries (Finland, Hungary, Italy, the Netherlands, Norway, Scotland and Sweden) and was financed by the European Union's Seventh Framework Programme during 2010–2014. The overall aim of EuroHOPE was to evaluate the performance of healthcare systems in terms of quality and use of resources. Based on linkable patient-level data gathered from multiple national registers and other data sources, the project took on a disease-based approach by considering five disease groups: ischemic stroke, hip fracture, acute myocardial infarction, breast cancer, and very low birth weight and preterm infants. A sub-sector level approach was also applied by using patient-level register data from the Nordic countries, with the specific objective to examine healthcare productivity (69).

In a first step, performance indicators and methods, such as standardised risk adjustment procedures, suitable for intra- and international register-based healthcare benchmarking, were developed. National disease-specific databases appropriate for this type of performance measurement and comparison were further created (Figure 4). Detailed descriptions of the data, indicators and methods are available on the project's web page (www.eurohope.info). In a second step, Europe-wide benchmarking of various performance indicators was performed. Variations in the performance between and within participating countries were described and reasons behind the variations were explored. Further, the relationship between costs and outcomes was investigated (69).

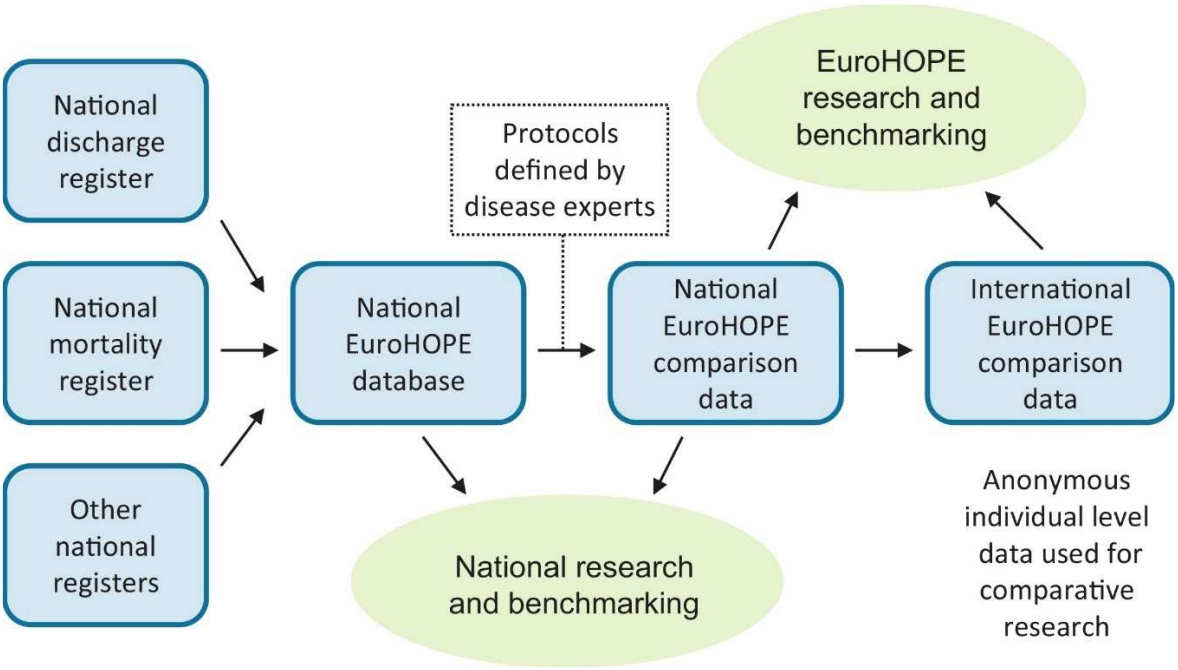


Figure 4. The creation of the EuroHOPE databases. Adopted from Häkkinen et al., 2013 (69).

An important general finding from the project was that the observed differences in performance at the country, region and hospital levels could not be explained by the demand and supply variables included (such as age structure, gross domestic product (GDP) per capita, education,

unemployment, density of population and concentration of hospital care). This indicated that there was room for performance improvement, which underlines the significance of benchmarking. The project concluded that this type of standardised data collection and comparisons was highly feasible. However, to have an impact on healthcare performance, the process would need to be carried out routinely (70, 71). After the end of the EuroHOPE project, the work continued as part of the BRIDGE Health project (BRidging Information and Data Generation for Evidence-based Health policy and research), supported by the European Union's Health Programme (www.bridge-health.eu).

3.3.2 A coordination project initiated by SHAR

In 1979, SHAR (which has recently decided to merge with the Swedish Knee Arthroplasty Register and form the Swedish Arthroplasty Register) started their data collection, making it one of the oldest national quality registers for healthcare in Sweden. The data are collected at the patient level from all orthopaedic departments in the country, both public and private providers, and used for performance measurements and comparisons. Each year, the results are presented in publicly available reports with the objective to map surgical techniques, complications and patient-experienced results in order to improve the care of patients undergoing hip replacement surgery (72).

Central to this thesis was a research database created in a coordination project initiated by SHAR in 2014. Within this project, data were collected from multiple national registers provided by SHAR, the National Board of Health and Welfare and Statistics Sweden. The data were linked at the patient level and encompassed information on around 300,000 operations between 1992 and 2013, with long-term follow-up. The database has since been extended to include patients who have undergone surgery in more recent years.

The research database was created to foster analyses of the departments and their activities as well as clinical research. It has served as a starting point for clinical improvement work and several research projects, including a major part of this thesis. The cooperation process as well as the details of the database (hereafter referred to as the SHAR coordination research database) are described more fully in Cnudde et al. (7).

4 MATERIAL AND METHODS

The thesis includes four studies, all of which were observational and retrospective. Some aspects of the research design were similar between the studies, such as the use of register data and quantitative analysis, while other aspects differed, such as the empirical setting and level of analysis. Study I was conducted in an international context and was based on the EuroHOPE research database (Setting 1). The study aimed at comparing the performance for the surgical treatment of hip fractures. Studies II–IV were conducted in the Swedish context and were all based on the SHAR coordination research database (Setting 2). While Study II was focused on the productivity development of hip replacement surgery at orthopaedic departments in Sweden, Studies III and IV aimed at investigating the effects on various performance indicators of a regional reform involving competition and bundled payment for hip replacement surgery. In these different research approaches, various statistical methods were applied. An overview of the characteristics of Studies I–IV is presented in Table 1.

Table 1. Overview of study characteristics.

	Study I	**Study II**	**Study III**	**Study IV**
Study focus	Associations between selected country- and region-level factors and mortality rates and LOS	Productivity development, including changes in efficiency and technology	Effects of competition and bundled payment on LOS, adverse event rate and patient satisfaction	Effects of competition and bundled payment on PROMs
Study setting	Hospital inpatient care in seven European countries	Orthopaedic care at 65 departments in Sweden	Orthopaedic care in Sweden, reform involving competition and bundled payment in Region Stockholm	Orthopaedic care in Sweden, reform involving competition and bundled payment in Region Stockholm
Study design	Register-based, cross-sectional	Register-based, longitudinal	Register-based, repeated cross-sections, quasi-experimental	Register-based, repeated cross-sections, quasi-experimental
Study population	Surgically treated hip fracture patients	Patients who underwent elective hip replacement surgery due to osteoarthritis	Patients who underwent elective hip replacement surgery due to osteoarthritis	Low-risk patients who underwent elective hip replacement surgery due to osteoarthritis
Data collection	Register data (national patient and mortality registers), 2007 (2009 in Norway)	Register data (SHAR, national patient register), 2005–2012	Register data (SHAR, LISA, national patient and mortality register), 2005–2012	Register data (SHAR, LISA, national patient and mortality register), 2008–2012
Data analysis	Regression analysis	Malmquist Productivity Index	DiD analysis	Entropy balancing, DiD analysis

Notes: LISA, Longitudinal Integrated Database for Health Insurance and Labour Market Studies.

4.1 STUDY I

4.1.1 Setting

Hip fracture is a serious injury that is common worldwide. It was estimated that 1.6 million hip fractures occurred globally in 2000 (73) and the number is expected to reach 6.3 million by 2050 (74). Hip fractures are an important cause of morbidity and mortality, especially in the elderly population. Furthermore, hip fractures are associated with high medical care costs.

In Study I, the performance for the surgical treatment of hip fractures was studied in the following seven European countries: Finland, Hungary, Italy (one region and one town), the

Netherlands, Norway, Scotland and Sweden. Several features of the healthcare systems differ between the countries. For example, five of the countries have tax-based systems (Finland, Italy, Norway, Scotland and Sweden), while Hungary and the Netherlands have social insurance systems. The main feature distinguishing these two groups is the level of integration between payers and providers. Furthermore, the level of decentralisation varies, with Finland having the most decentralised system, where hospital districts are responsible for hospital care. In Norway and Scotland, the central governments are responsible for healthcare delivery. Common to the seven countries was the use of prospective payment systems during the study period, some with elements of cost compensation. In Hungary, Italy, the Netherlands and Norway, activity-based funding models were applied, where the Netherlands used diagnosis-related group (DRG)-based funding, while Italy and Norway combined activity-based funding based on the DRG system and global budgets. Fixed payment systems, i.e., global budgets, were used in Finland and Scotland. In Sweden, reimbursement schemes differed between regions, with global budgets and activity-based funding based on DRGs being the most commonly used.

Another important difference between the countries is the overall economic situation, which may affect healthcare performance. In 2008, Norway had the highest GDP per capita, whereas Hungary had the lowest.

Regarding the treatment of hip fractures, there are no internationally accepted clinical guidelines. Nevertheless, five of the countries (Finland, the Netherlands, Norway, Scotland and Sweden) developed and published national clinical guidelines in the 2000s. These guidelines generally focus on the maximum waiting time for surgical treatment (24 hours) and which surgical procedure to use.

4.1.2 Data and study population

For Study I, the national EuroHOPE comparison databases for hip fractures in the included countries were utilised. These databases were created using common protocols and by linking data from multiple national sources, including patient registers and mortality registers, through the use of personal identification numbers (Figure 4). Due to national data regulations, it was not possible to pool patient-level data from all countries. However, exceptions could be made in Finland, Hungary, Italy and Sweden, making it possible to pool patient-level data, with some restrictions.

Hip fracture was defined as femoral neck fracture, pertrochanteric fracture or subtrochanteric fracture. The surgical procedures included were total and partial prosthetic replacement, internal fixation and external fixation of the hip joint. Patients were included if they had been admitted to hospital inpatient care due to hip fracture and undergone one of the included surgical procedures in 2007. For Italy, data were only available from one region (Lazio) and one town (Turin). In Norway, data from 2007 were not available; hence, patients with a hip fracture in 2009 were included instead. Patients who were younger than 50 years of age, had

an extremely long LOS or had incomplete personal identification numbers, as well as tourists, were excluded from the study.

In addition, variables at the country (funding type and availability of national clinical guidelines) and region level (GDP per capita, population density, Herfindahl-Hirschman index (a common measure of market concentration), the number of hip fracture cases among those above 50 years per 100,000 inhabitants, and share of males) were collected from the statistical database of the Organisation for Economic Co-operation and Development and from national statistics bureaus. Regions in Finland, Italy, the Netherlands, Norway, Scotland and Sweden refer to local authorities responsible for healthcare, while regions in Hungary are based on a regional governmental division. Regions with incomplete data or fewer than 100 hip fractures were excluded.

4.1.3 Performance indicators

The performance for the surgical treatment of hip fractures was compared across and within the seven countries in Study I. Performance was measured as 30-day and one-year all-cause mortality rates and LOS of the first hospital episode in acute care (including hospital transfers) and during a follow-up period of 365 days following hip fracture.

4.1.4 Statistical analyses

The national comparison databases were used to calculate aggregate region-level risk-adjusted performance indicators. For each region, age- and sex-adjusted mortality rates and LOS were calculated based on the ratio between observed and predicted values. The pooled patient-level data from Finland, Hungary, Italy and Sweden were used in negative binomial regression models (logistic regression) to calculate coefficients in order to predict mortality rates and LOS.

To determine how much of the variance of the indicators was attributable to cross-country differences and regional differences, respectively, one-way random effects analysis of variance models were applied.

Region-level analyses were performed to assess associations between the risk-adjusted indicators and the aforementioned country- and region-level variables. To assess the associations between indicators and explanatory variables, fixed (M1) and random effects models (M2) were applied. The Hausman test was used to select the most appropriate model of these two. A third model (M3) was further applied where the country-level fixed effects (country indicators) were replaced with fixed-effects variables for funding type and availability of clinical guidelines.

4.2 STUDIES II–IV

4.2.1 Setting

Total hip replacement surgery is a common procedure worldwide. In Sweden, more than 18,000 hip replacements surgeries are performed every year, with the majority of the patients suffering from osteoarthritis (72). With an increasing incidence, and an aging and growing population, the number of surgeries is expected to rise (75).

The 21 regions in Sweden are responsible for the funding and delivery of healthcare, through a decentralised tax-based healthcare system. Specialised somatic care, such as hip replacement surgery, is usually provided by region-owned hospitals, but also by privately owned, often specialised, hospitals which are publicly regulated and financed. There are roughly 75 orthopaedic providers performing hip replacement surgery, and these can be grouped as university, central or local hospitals and private specialised centres. They are in general reimbursed through the DRG model, either as a basis for a budget or as activity-based funding.

In Study II, the productivity development of the orthopaedic departments providing total hip replacement surgery in Sweden was analysed. In Studies III and IV, the focus shifted from the level of departments to Region Stockholm, where a competition-promoting reform changed the market for hip and knee replacement surgery in 2009. Prior to the reform, patients were traditionally referred to and treated by the region-owned hospitals. However, with the reform, private providers were invited to the market through accreditation and low-risk profile patients were allowed to choose provider, thus creating competition for patients. In addition, the reform also introduced a bundled payment model for the reimbursement of providers. In this model, providers are given a single payment to cover costs for a defined episode of care, including surgery, pre- and post-operative care, and adverse events. Previously, a DRG-based arrangement was used (76). Apart from empowering the patient to make a choice, the reform sought to improve quality and efficiency by means of competition and economic incentives, as well as to increase access in order to shorten waiting times.

4.2.2 Data and study population

Studies II–IV were all based on the SHAR coordination research database. Common for the studies was the inclusion of patients who underwent elective total hip replacement due to osteoarthritis. Patients younger than 18 years, who underwent bilateral hip replacement or who had a prior hip replacement within 90 days of the surgery were excluded. Patients with missing information essential for the analyses (for example, patients with a missing or incorrect DRG code in Study II, and patients with missing information on any of the included confounders in Studies III and IV) were also excluded.

In Study II, SHAR was used to identify and obtain data on patients who underwent surgery between 2005 and 2012. For each patient, administrative data on their hospital inpatient stays related to the surgery were retrieved from the national patient register. All orthopaedic departments in Sweden were eligible for inclusion in the study. However, a few of them had to

be excluded due to inabilities to match their data between SHAR and the national patient register, no or low completeness in the national patient register, or their entering (exiting) of the market during the last (first) year of the study period. Moreover, departments that were affected by reorganisations during the study period, such as mergers and splits, were considered to be the same unit during the entire study period. A total of 65 departments were included in the analysis after these exclusions. The departments' production-related costs were provided by the National Board of Health and Welfare and the Swedish Association of Local Authorities and Regions through their cost per patient database (77).

In Studies III and IV, patients who underwent surgery in a region other than their registered residential region and patients at a private specialised centre in Stockholm that mainly operates on privately insured patients and therefore was not affected by the reform were further excluded. In Study III, patients who underwent surgery in 2005–2012 were included and data were retrieved from SHAR (information about the surgery and patient), the national patient register (information on hospital inpatient stays related to the surgery and previous use of inpatient care), the national mortality register (information on deaths) and the Swedish Longitudinal Integrated Database for Health Insurance and Labour Market Studies (information on patient demographics). Study IV included patients between 2008 and 2012. Additional inclusion criteria in Study IV were that the patients were at low risk (American Society of Anaesthesiologists grades 1 or 2) and thus covered by the reform, and had a body mass index between 15 and 50. Data on the surgery and PROMs, previous use of inpatient care, and patient demographics were collected from SHAR, the national patient register and the Swedish Longitudinal Integrated Database for Health Insurance and Labour Market Studies, respectively.

For Studies III and IV, a questionnaire (provided in Appendix A, in Swedish) was sent out to all regions to gather information regarding how the providers were reimbursed for this type of surgical procedure. Furthermore, I held an interview with one of the representatives from the third-party payer that was involved in designing the reform, in order to gain a better understanding of what prompted the reform and how it worked in practice. Moreover, to understand the perspective of a hip replacement patient, I followed a patient during one day, from hospital admission to surgery and recovery. The following day, I made another visit to see how the patient was feeling and how the discharge was planned.

4.2.3 Performance indicators

In Study II, the departments' development in productivity in the provision of total hip replacement surgery was assessed by relating the number of surgeries to the costs associated with the surgeries. The productivity development was also decomposed into changes in efficiency and technology.

The performance indicators in Studies III and IV were selected to provide a multidimensional assessment of the effects of the reform. While Study III captured aspects of resource use (LOS of surgical admission) and quality, based on both medical outcomes (adverse events within 90

days following surgery) and PROMs (share of patients satisfied with the outcome of the surgery), Study IV focused on hip replacement surgery quality as captured by PROMs of health gain (indicated by the EQ-5D index and a visual analogue scale (VAS) for health status), pain reduction (VAS) and level of satisfaction (VAS) one and six years post-surgery.

4.2.4 Statistical analyses

To measure the productivity development in Study II, the input and outputs in the orthopaedic departments' production function were first defined. The single input was defined as the estimated departmental costs associated with hip replacement surgery. These costs consisted of a fixed cost for the surgery, a variable cost corresponding to the LOS of the surgical admission, and costs of any adverse events within 90 days following surgery. The fixed and variable costs of the surgery were estimated using national averages for the DRGs which include hip replacement surgery, whereas the costs for adverse events were calculated using DRG weights corresponding to the specific diagnoses of the adverse events. The numbers of non-cemented, hybrid and cemented hip replacements were defined as three different outputs. The input and outputs were then summarised by department and year.

Second, following the approach developed by Färe et al. (78), input-oriented Malmquist Productivity Indices to measure the productivity development were calculated. These indices have a few attractive properties, including that information on input or output prices is not required in their construction and there is no need for an assumption regarding the organisations' behaviour (e.g., profit maximisation or cost minimisation), which is useful in situations where such information is missing. Another desirable feature is that the indices can be decomposed into economically relevant components of productivity change: changes in efficiency and technology, respectively (79).

Furthermore, as costs defined the input, cost-based Malmquist indices were constructed (80). The indices were calculated by relating changes in each of the departments' production from one year to the next, and by comparing the production to the production frontier of the so-called best practice. Because of innovation and technological change, this frontier shifts over time. The indices of productivity change can accordingly be decomposed into efficiency change and technological change, where the former is associated with changes in the departments' observed production relative to the maximum potential production ('the catch-up effect') and the latter is associated with shifts in the frontier (78, 80).

To test the null hypothesis of no change in productivity, efficiency and technology, a bootstrap technique was applied (81, 82). In the sensitivity analyses, variations in the cost calculations, different model specifications, and outlier removals were applied. The calculations of the Malmquist indices were performed in the R software using the FEAR package (83).

Studies III and IV were quasi-experimental studies in which the commonly used difference-in-difference (DiD) analytical framework was applied to estimate causal effects of the reform. Within this framework, changes in an outcome before and after an intervention for a treatment group are compared with changes of the same outcome for a control group. It is assumed that

unobservable confounders that vary across groups are fixed over time, and thus cancel each other out, which allows for identification of treatment effects while controlling for these unobservable confounders (although without explicitly measuring them). Moreover, unobservable confounders that vary over time are assumed to be fixed between groups. Thus, in the absence of the intervention, the groups would have experienced the same changes in outcomes. This is referred to as the parallel trend assumption (84-87).

Since the reform was introduced only in Region Stockholm (at least during the study period), patients in this area formed the intervention group, while patients in other regions formed the control group. Repeated cross-sections were constructed and the data were collapsed into two periods, pre-reform (2005–2008 in Study III and 2008 in Study IV) and post-reform (2009–2012 in both studies), to avoid issues of serially correlated outcomes (88). In both studies, and for all performance indicators, the DiD analyses were performed using regression modelling, with and without controlling for confounders. Generalised estimating equations were used to solve linear regression models, while accounting for clustering of patients within hospitals. All statistical analyses were performed using the SAS software, version 9.4 (89).

In Study III, the mean outcomes per year and group were plotted to validate the assumption of parallel trends. The assumption was also tested in simple linear trend models by assessing the significance of the interaction between time and group in the pre-reform period (85). The following confounders were included in Study III: sex, age group, educational level, civil status, and level of comorbidity as indicated by Elixhauser Comorbidity Index. In Study III, the DiD analyses were further stratified by hospital type (university, central and local hospitals and private specialised centres) to examine whether the reform had heterogenous effects across various hospital types with differences in patient case mix. To test the robustness of the results, various sub-samples of low-risk patients and patients from regions with a similar hospital structure as Stockholm were considered.

In Study IV, the assumption of parallel trends could not be investigated due to data being available only from 2008. Instead, entropy balancing was used prior to the DiD analyses to account for potential time-varying confounding (90). Entropy balancing is a data pre-processing method which makes use of a reweighting scheme to create weights for all observations so that the confounder distributions in the reweighted treatment and control groups satisfy a set of prespecified balance constraints. In this process, differences in the distributions with respect to the first, second or higher moments are precisely adjusted for (91, 92). The entropy balancing algorithm was applied to achieve balance in the mean and variance of observable characteristics between the treatment and control groups. The algorithm was applied three times to make the patients in Stockholm in the pre-period and the patients in the control group in the pre- and post-periods comparable to the patients in Stockholm in the post-period (90, 93). The following confounders were included: sex, age, body mass index, American Society of Anaesthesiologists grade, Charnley classification (a patient self-reported comorbidity grouping for walking ability), surgical approach, level of comorbidity as indicated by Elixhauser Comorbidity Index, civil status, educational level, and pre-operative values of

each respective PROM (satisfaction excluded, as it was measured only post-operatively). Moreover, the balancing was performed separately for each outcome and follow-up period. The balance was assessed by comparing weighted means and variances of the confounders.

The DiD analyses in Study IV were thereafter performed using weighted regression modelling with the weights produced by the entropy balancing, with and without controlling for the same set of confounders used in the balancing algorithm (90, 94). In a first sensitivity analysis, inverse probability of treatment weighing to create balance between the groups was applied (95). In a second sensitivity analysis, the entropy balancing scheme was simplified and estimated weights so that the treatment groups would be balanced, although without considering the time dimension (i.e., the algorithm was applied twice: first, to make the patients in the pre-period control group comparable to the patients in Stockholm in the pre-period; second, to make the patients in the post-period control group comparable to the patients in Stockholm in the post-period).

4.3 ETHICAL CONSIDERATIONS

For Study I, the Regional Ethics Review Board in Stockholm, Sweden, approved the part of the research carried out in Sweden (reference number 2011/213-31). Similar ethical approvals were applied for (and granted) in the other countries. Ethical approvals for Studies II–IV were granted by the Regional Ethics Review Board in Gothenburg, Sweden (reference numbers 271-14, T695-14 and 2020-00072).

The thesis, consisting of four register-based studies, was based on two comprehensive patient-level datasets containing sensitive information on patients with hip osteoarthritis and hip fracture. The data were collected from multiple national registers and were linked by the responsible government agencies through use of personal identification numbers. Thereafter, the data were pseudonymised before being distributed to the researchers involved in the two projects that form the basis for this thesis.

In register-based research, ethical aspects concern the role of informed consent and the protection of the integrity of study participants. Although the Declaration of Helsinki states that informed consent from study participants is required to conduct research (96), it is generally not a requirement for large-scale, register-based studies. As discussed by Ludvigsson et al. (97), arguments for this include that the large number of study participants makes it difficult, if not impossible, to obtain consent from all participants. The costs for this process would also be unreasonable. Moreover, requirements of consent would likely result in significantly reduced participation rates and lead to severe selection bias in specific groups (e.g., among immigrants and children). Provided that the research is ethically sound, it is assumed that study participants do not object to register-based research (97). For these reasons, the need for informed consent in register-based research is generally waived by an ethics review committee, as was the case for the studies included in this thesis.

The registration of patients in national quality registers, such as SHAR, can be related to what is mentioned above. At registration, patients are informed that their data may be used for research. Should a patient wish to opt out, the patient can do so at any time and have their record deleted, in accordance with the Swedish Patient Data Act (98).

To protect the integrity of study participants, precautionary measures have been taken in the performance of the studies included herein. First, the datasets were pseudonymised before being transferred to the researchers. Thus, data containing personal information that would have made it possible to identify individuals, such as name, personal identification number and address, were at no stage processed by the researchers. Second, the data were stored on password-protected servers and could only be accessed by the researchers involved in the project. Third, the studies did not involve any contact between researchers and study participants. Fourth, the datasets were relatively large and all results were presented at an aggregated level, meaning that the risk of individual identification may be considered negligible.

It should also be noted that during the work related to this thesis, I was employed by the Centre for Health Economics, Informatics and Health Services Research in Region Stockholm. This may constitute a potential risk of conflict of interest regarding Study III and Study IV, as these studies analysed the impact of a political reform undertaken within and by the region. On the other hand, the Centre for Health Economics, Informatics and Health Care Research operates independently from the region and has strong connections to the academic world, and the studies followed a strictly academic process in their design and execution.

5 FINDINGS

5.1 PERFORMANCE OF SURGICAL TREATMENT OF HIP FRACTURE (STUDY I)

5.1.1 National and regional differences

A total of 59,605 patients with hip fracture residing in 102 regions in the seven European countries were included in Study I. In the calculation of age- and sex-adjusted indicators for all-cause mortality (30-day and one-year) and LOS (of first hospital episode and during a follow-up of 365 days) following hip fracture, marked differences were revealed in all four indicators, both across and within countries. At the country level, the highest 30-day and one-year mortality rates were observed in Hungary (13.7% and 39.7%, respectively), whereas the lowest mortality rates were observed in Italy (4.0% and 19.1%, respectively). While Norway showed the shortest LOS of the first hospital episode (9.6 days), and Hungary had the shortest LOS during 365 days (11.1 days), Italy had the longest LOS of both the first hospital episode (18.7 days) and during 365 days (23.3 days).

The analysis of variance revealed that 73% of the variation in age- and sex-adjusted 30-day mortality rate was attributable to country-level differences, whereas 27% of the variation was due to regional differences. For risk-adjusted one-year mortality rate, the proportion of variance caused by differences at the country and region level was 88% and 12%, respectively. For both indicators on risk-adjusted LOS, 57% of the variation was attributable to the country level and 43% to the region level.

5.1.2 Associations with selected country- and region-level variables

In the analysis of associations between selected country- (funding type and availability of national clinical guidelines) and region-level variables (GDP per capita, population density, Herfindahl-Hirschman index, the number of hip fracture cases among those above 50 years per 100,000 inhabitants, and share of males) and the performance indicators (Study I), the Hausman test suggested fixed effects models (M1) for all indicators but one-year mortality rate, for which a random effects model (M2) was preferred. In M3, the country-level fixed effects (country indicators) were replaced with fixed-effects variables for funding type and the availability of clinical guidelines. The results from Study I are presented in Table 2. As shown, there were significant differences in mortality rates and LOS between the countries. For example, in comparison with Finland, Italy had a 4.6 percentage points lower 30-day mortality rate (M1) and a 6.7 percentage points lower one-year mortality rate (M2). Hungary, however, had higher mortality rates (5.4 and 13.2 percentage points higher for 30-day and one-year mortality rates, respectively) than Finland (M1 and M2).

Moreover, compared with Finland, Sweden and Italy had longer LOS both of the first hospital episode (4.2 and 8.5 days longer, respectively, M1) and during the one-year follow-up (4.3 and 7.3 days longer, respectively, M1). Hungary, however, was found to have a 2.9 days shorter LOS during one year compared with Finland (M1). Furthermore, while fixed budgets did not

have any significant effect on any of the indicators, the availability of clinical guidelines was associated with decreased mortality rates (between 3.9 and 9.9 percentage points) and 4.2 days longer LOS during one year (M3).

At the regional level, a higher share of males was found to be associated with a higher 30-day mortality rate and shorter LOS (M3).

Table 2. Results from fixed and random effects models.

	30-day mortality rate		**One-year mortality rate**		**LOS first episode**		**LOS during 365 days**	
	M1	**M3**	**M2**	**M3**	**M1**	**M3**	**M1**	**M3**
Intercept	12.58***	7.84**	26.04***	30.80***	10.23*	29.76***	15.13**	23.99***
	(3.11)	(2.81)	(4.46)	(5.55)	(4.22)	(3.59)	(4.83)	(3.90)
GDP/capita	-0.00	-0.01	-0.01	-0.01	0.00	-0.01	0.01	0.00
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
Population density	-0.00	-0.03	0.04	-0.05	-0.01	0.02	-0.02	0.02
	(0.03)	(0.04)	(0.04)	(0.08)	(0.04)	(0.05)	(0.04)	(0.06)
HHI	-1.16	-1.32	-1.18	-3.18	-0.61	-1.81	-0.43	0.21
	(0.98)	(1.29)	(1.43)	(2.54)	(1.33)	(1.64)	(1.52)	(1.78)
Share hip fractures	-0.04	-0.07	0.00	-0.06	-0.04	0.05	-0.02	0.08
	(0.04)	(0.05)	(0.06)	(0.10)	(0.05)	(0.06)	(0.06)	(0.07)
Share males	-0.10	0.20*	0.05	0.30	-0.02	-0.54***	0.00	-0.34**
	(0.09)	(0.09)	(0.13)	(0.17)	(0.12)	(0.11)	(0.13)	(0.12)
Fixed budget		0.61		2.68		-0.28		-1.90
		(0.72)		(1.43)		(0.92)		(1.00)
Clinical guidelines		-3.94***		-9.91***		2.09		4.21**
		(1.00)		(1.98)		(1.28)		(1.39)
Country indicators								
Sweden	-1.31*		-3.11		4.23***		4.28***	
	(0.64)		(2.46)		(0.86)		(0.99)	
Hungary	5.40***		13.24***		1.35		-2.92*	
	(0.87)		(1.06)		(1.18)		(1.35)	
Italy	-4.57***		-6.74**		8.51***		7.27***	
	(1.22)		(2.37)		(1.65)		(1.89)	
Netherlands	-1.09		-2.11		3.35**		1.60	
	(0.92)		(11.63)		(1.24)		(1.42)	
Norway	-0.43		-2.72		-1.14		0.09	
	(0.84)		(3.49)		(1.14)		(1.30)	
Scotland	-1.23		3.40***		7.54***		2.61	
	(0.94)		(0.86)		(1.28)		(1.46)	
Finland			-1.96					
			(1.06)					
Adj. R-squared	0.72	0.43	0.03	0.53	0.57	0.22	0.53	0.22
F statistics	23.53***	11.13***	0.24	16.32***	12.68***	4.86***	10.79***	4.95***

Notes: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$. M1 = fixed effects model, M2 = random effects model, M3 = fixed effects model. HHI, Herfindahl-Hirschman index.

5.2 PERFORMANCE OF ELECTIVE HIP REPLACEMENT SURGERY (STUDIES II–IV)

5.2.1 Development in productivity, efficiency and technology

The productivity development of the provision of total hip replacement surgery between 2005 and 2012 was evaluated in Study II. The productivity development, measured by Malmquist Productivity Indices, was further decomposed into changes in efficiency and technology. A total of 65 orthopaedic departments providing total hip replacement surgery was included in the study. The average number of surgeries per department increased over time: from 157 surgeries on average in 2005 to 187 surgeries on average in 2012. Regarding the input variable (costs of hip replacements), no clear trends were observable. While the highest total cost for the average department was observed in 2009, the lowest total cost was observed in 2006. However, the mean cost of a single hip replacement surgery decreased over time: from SEK 93,000 in 2005 to SEK 83,000 in 2012. Approximately 4–5% of the operations per year were followed by an adverse event.

The overall results from the study are presented graphically in Figure 5, where averages of changes in productivity (Malmquist Productivity Index), efficiency and technology are shown. The averages were calculated as the geometric mean of the results from the 65 departments. The error bars represent 95% confidence intervals. A value above one indicates progress between two consecutive years, whereas a value below one indicates regress. A value of 1 means no change.

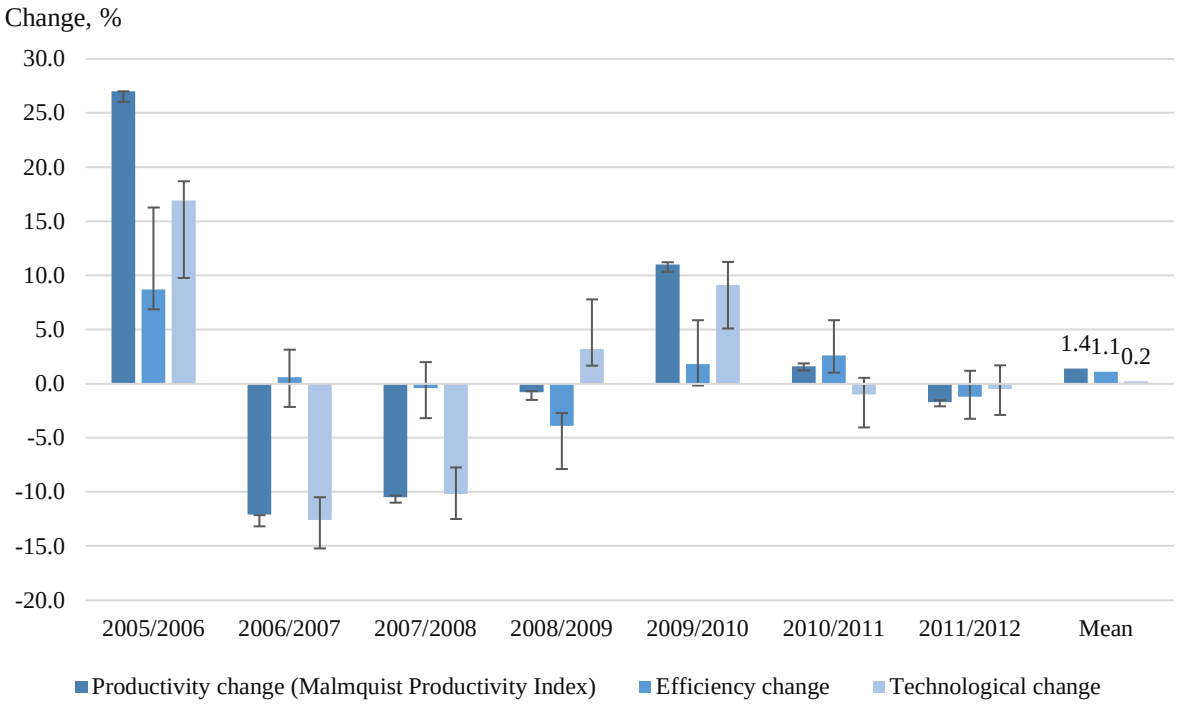


Figure 5. A graphical representation of the results of productivity change (Malmquist Productivity Index) and its components. A value = 1 indicates no change between two consecutive years, > 1 indicates progress and < 1 indicates regress. The error bars represent 95% confidence intervals.

As presented in Figure 5, an average productivity increase of 1.4% per year was noted over the study period. This development was due mainly to changes in efficiency (1.1%), rather than changes in technology (0.2%). The results broken down by year show that productivity progress was found in three periods (ranging from 1.6% to 27.0%), whereas a regress was found in four periods (ranging from 0.8% to 12.1%). These changes were statistically significant. Furthermore, efficiency improved significantly in two periods (between 2.6% and 8.7%) and deteriorated significantly in one period (3.9%). Significant progress in technology was achieved in three periods (ranging from 3.2% to 16.9%), whereas a significant regress was experienced in two periods (between 10.2% and 12.6%).

The department-specific Malmquist indices are presented in Table 3, whereas changes in efficiency and technology are presented in Appendix B and C, respectively. Inspection of the results shows that none of the orthopaedic departments had continuous progress or regress in productivity, efficiency or technology during the study period.

Table 3. Malmquist productivity indices; mean (geometric), 2005–2012, 65 departments.

Department	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
1	0.911	0.945*	0.924*	1.124*	1.120*	0.993	0.941*
2	1.231*	0.858*	0.851*	1.005	1.218*	0.925*	0.992*
3	1.300*	0.760*	0.914*	0.972	1.044*	0.974	0.989
4	1.308*	0.817*	0.848*	0.951*	1.108*	1.015	0.960*
5	1.323*	0.887*	0.981*	0.971*	1.041*	0.978	0.952*
6	1.206*	0.897*	0.936*	0.941*	1.060*	1.034*	0.967*
7	1.371*	0.868*	0.872*	1.034*	1.173*	1.037	0.934*
8	1.359*	0.874*	0.971*	0.969*	1.106*	0.971*	0.974*
9	1.352*	1.047	0.988*	0.965*	1.086*	0.929*	1.013*
10	1.259*	0.946*	0.817*	1.005	1.109*	0.997	0.937*
11	1.257*	0.796*	0.857*	1.008*	1.100*	1.089*	0.984*
12	1.358*	0.871*	0.902*	0.808*	1.228*	1.070*	0.967*
13	1.196*	0.882*	0.846*	1.021*	1.078*	1.122*	0.964*
14	1.214*	1.047	0.863	1.038	1.023*	0.979	1.002
15	1.317*	0.894*	0.873*	0.939*	1.131*	0.971*	1.016
16	1.338*	0.892*	0.905*	0.969*	1.209*	1.026	0.957*
17	1.375*	0.888*	0.929*	0.987*	1.193*	1.110*	0.896*
18	1.363*	0.861*	0.895*	1.038*	1.170*	1.033*	1.046*
19	1.064*	0.946*	0.920*	0.976*	1.052	1.002	0.994
20	1.254*	0.815*	0.911*	1.022*	1.105*	1.034*	1.074*
21	1.280*	0.906*	0.953*	0.994	1.060*	1.037*	0.956*
22	1.236*	0.897*	0.821*	1.006*	1.151*	1.179*	1.034*
23	1.275*	0.806*	0.966*	1.087*	1.091*	1.045*	0.932*
24	1.307*	0.867*	0.904*	1.008*	1.153*	0.939*	0.886*
25	1.190*	0.850*	0.925*	0.974	1.016*	1.011*	1.031*
26	1.303*	1.057	0.767*	1.051*	0.994	1.017	0.938*
27	1.154*	1.011	0.988	0.856*	0.999	0.988	0.987*
28	1.272*	0.907*	0.920*	0.878*	1.067*	0.959	1.013
29	1.202*	0.936*	0.889*	0.954*	1.070*	1.002	1.015

Department	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
30	1.313*	0.790*	0.882*	1.031*	1.253*	0.982	1.135*
31	1.319*	0.804*	0.923*	0.920*	1.150*	1.027*	0.952*
32	0.975	1.031	0.864*	1.032*	1.131*	0.913	1.039
33	1.232*	0.806*	0.927*	0.960*	1.289*	0.964*	1.090*
34	1.187*	0.924*	0.868*	0.981*	1.073*	1.066*	0.996
35	1.188*	0.881*	0.949*	1.058*	1.123*	1.024*	0.982
36	1.689*	0.682*	0.943*	1.028*	1.197*	1.062*	0.907*
37	1.217*	0.828*	0.952*	0.966*	1.085*	0.922*	0.946*
38	1.285*	0.926*	0.944*	0.993	1.035*	1.050*	0.871*
39	1.186*	0.859*	0.888*	1.026*	1.078*	1.021*	0.965*
40	1.417*	0.880*	0.861*	0.990*	1.154*	1.123*	0.993*
41	1.351*	0.831*	0.960*	1.022*	1.127*	1.026*	0.991
42	1.166*	1.013	0.852*	0.987	1.276*	0.932*	1.012
43	1.261*	1.221*	0.657*	1.045*	1.096*	1.138*	1.037*
44	1.105*	0.922*	0.900*	0.855*	1.298*	0.977*	1.029
45	1.325*	0.856*	0.912*	1.008*	1.071*	1.070*	1.087*
46	1.307*	0.820*	0.920*	0.924*	1.071*	1.007	1.015*
47	1.297*	0.894*	0.963*	1.010	0.967	1.048*	1.050*
48	1.331*	0.859*	0.794*	1.035*	1.106*	1.084*	0.979*
49	1.250*	0.878*	0.929*	1.015*	1.076*	1.006*	0.908*
50	1.581*	0.885*	0.803*	1.067*	1.076*	0.981*	0.962*
51	1.306*	0.882*	0.859*	1.053*	1.089*	0.988*	0.956*
52	1.331*	0.852*	0.901*	0.997	1.124*	0.984	0.999
53	1.235*	0.839*	0.912*	0.945*	1.118*	1.009	0.997
54	1.321*	0.866*	0.809*	0.914*	1.044*	1.058*	0.947*
55	1.270*	0.807*	0.871*	0.912*	1.133*	0.970*	1.005
56	1.400*	0.819*	1.009	0.964*	1.076*	1.053	1.009
57	1.412*	0.878*	1.011	1.045	1.211*	0.967*	0.993*
58	1.160*	0.873*	0.770*	1.204*	0.964	1.076*	0.894*
59	1.343*	0.845*	0.937*	0.946*	1.100*	1.020*	0.966*
60	1.344*	0.897*	0.818*	0.922*	1.230*	1.078*	1.043*
61	1.279*	0.827*	0.925*	1.169*	1.146*	1.054*	0.986*
62	1.245*	0.841*	0.898*	1.040*	1.085*	0.927*	1.028*
63	1.223*	0.838*	0.907*	0.971*	1.101*	1.051*	0.953*
64	1.236*	0.831*	0.927*	0.991	1.138*	0.969*	0.942*
65	1.229*	0.823*	0.934*	1.038*	1.069*	1.071*	0.966*
Geometric mean	1.270*	0.879*	0.895*	0.992*	1.110*	1.016*	0.983*

Notes: The numbers show annual change between two consecutive years, = 1 indicates no change, > 1 indicates progress, < 1 indicates regress. * indicates statistically significantly different from 1.0 at 95% level.

The sensitivity analyses showed that the overall results were rather robust; productivity slightly increased over the study period in all models, with efficiency changes being the main contributor to this progress.

5.2.2 Effects of competition and bundled payment

In Studies III and IV, the effects of competition and bundled payment on the performance of hip replacement surgery were evaluated. Several performance indicators were investigated to provide a multidimensional assessment of the reform. A total of 85,275 observations were included in the main analysis of Study III, whereas 36,627 observations were included in the analysis of PROMs with a one-year follow-up (Study IV) and 18,145 observations were included for the six-year follow-up PROMs (Study IV). Table 4 presents how the observations were divided by group and period.

Table 4. Number of observations included in Study III and Study IV.

	Stockholm (treatment group)		**Other regions (control group)**	
	Pre-reform	**Post-reform**	**Pre-reform**	**Post-reform**
Study III				
LOS of surgical admission	6,380	8,190	32,799	37,906
Adverse events within 90 days	6,380	8,190	32,799	37,906
Share of satisfied patients	2,581	7,512	14,235	34,686
Study IV				
One-year follow-up PROMs	1,143	5,420	4,785	25,279
Six-year follow-up PROMs	1,004	2,259	4,205	10,677

Notes: In Study III, pre-reform = 2005–2008 (2007–2008 for share of satisfied patients). In Study IV, pre-reform = 2008. In both Study III and Study IV, post-reform = 2009–2012.

Descriptive statistics showed that the resource use, measured as LOS of surgical admission, declined over time (Study III) in both Stockholm (treatment group) and the other regions (control group). This can also be seen in Figure 6a. Patients in the control group had a longer LOS than patients in Stockholm, both before and after the reform. However, they approached Stockholm's level over time. Moreover, visual inspection of the trend of LOS (Figure 6a) and a statistical test validated the assumption of common trends prior to the reform. In the analysis of the effects of the introduction of competition and bundled payment in Stockholm, the results revealed that LOS increased in relation to the control group (Study III). However, as Figure 6a shows, LOS has still slightly decreased after the reform in Stockholm. As indicated in Table 5, the risk-adjusted decrease in LOS was 0.7 days lower (baseline LOS of 5.8 days) in Stockholm in comparison with the control group. In the analysis stratified by hospital type, it was revealed that this effect was driven mainly by university and central hospitals.

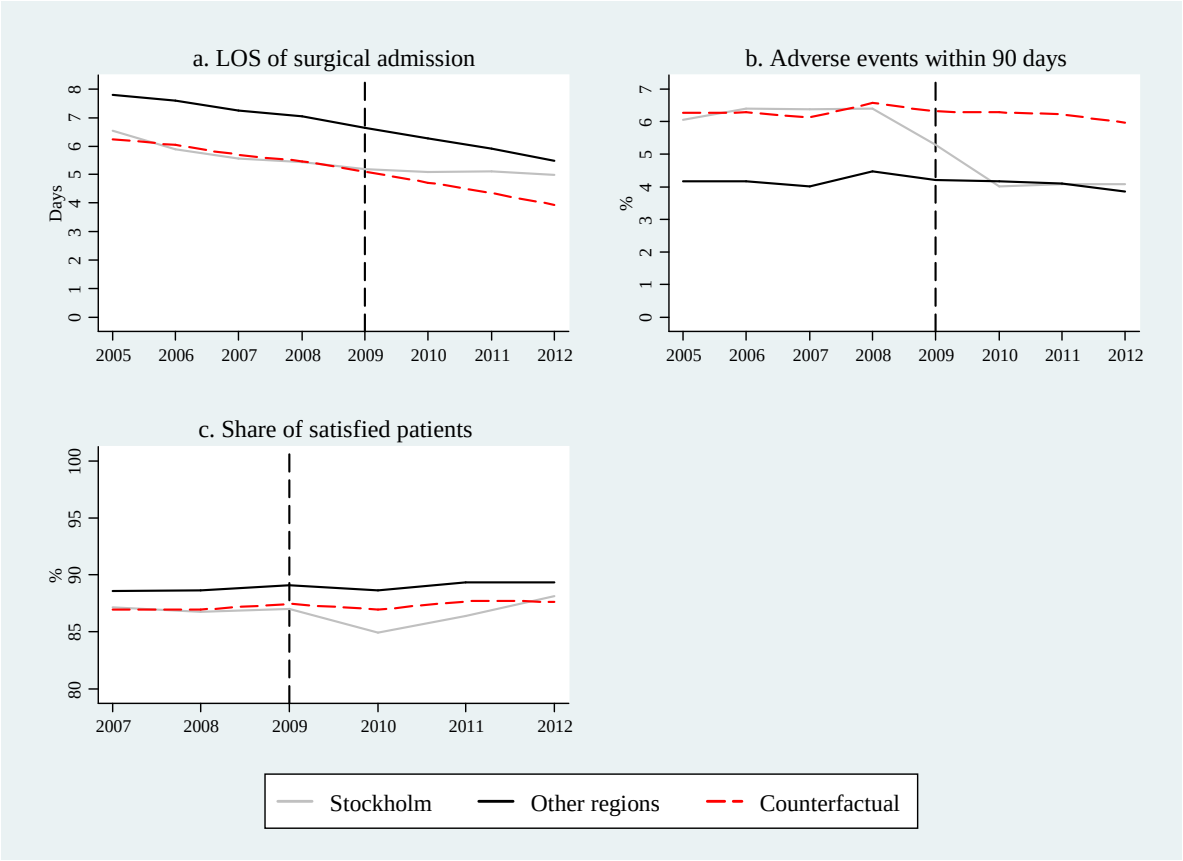


Figure 6a-c. Performance indicators per group over time and corresponding counterfactuals. The vertical reference line indicates the introduction of the reform.

The assumption of common trends for adverse event rates before the reform was also confirmed by visual inspection (Figure 6b) and a statistical test (Study III). Prior to the reform, the control group clearly had a lower rate of adverse events according to descriptive statistics and Figure 6b. However, while the control group experienced only a marginal decrease in their rate over time, Stockholm experienced a rather sharp reduction in the adverse event rate post-reform. The DiD analysis confirmed this, and indicated that the reform led to a significant decrease of 1.6–1.8 percentage points (Table 5) in the adverse event rate (baseline rate of 6.3 percent). Again, this effect was driven mainly by university and central hospitals according to the analysis stratified by hospital type.

Regarding the indicators on patient satisfaction with the outcome of the surgery, both the share of patients who were satisfied (Study III) and the level of satisfaction (Study IV) were similar across treatment groups and remained quite stable over time. As information regarding patient satisfaction was available only from 2007 (i.e., two years before the reform) in Study III, it was difficult to shed light on the validity of common trends (Figure 6c). Therefore, the results should be interpreted with caution. Nevertheless, in Study IV, balance in the included confounders was successfully achieved through the entropy balancing. This means that the results are more reliable, since time-varying confounding, which could affect the groups' trends differently, is accounted for. According to the DiD analyses in Studies III and IV, patient satisfaction was not affected by the introduction of competition and bundled payment (Table 5).

Similarly, Study IV showed that gains in EQ-5D index and health status as indicated on a VAS as well as pain reduction as indicated on a VAS after hip replacement surgery in Stockholm were comparable to those in the control group, at both one- and six-year follow-up. These indicators did not change over time. Again, the entropy balancing was successful in creating balance between the groups. Results from the DiD analyses indicated that the reform did not have any effect on these indicators.

The sensitivity analyses showed that the results in both studies were robust.

Table 5. Results from DiD analyses.

	Unadjusted		**Adjusted**	
Performance indicators	**DiD estimate**	**Std. err.**	**DiD estimate**	**Std. err.**
Resource use				
LOS of surgical admission	0.594**	0.271	0.669***	0.258
Quality				
Medical outcomes, 90-day follow-up				
Adverse event rate	-0.018***	0.006	-0.016**	0.007
PROMs, one-year follow-up				
Gain EQ-5D index	-0.004	0.017	-0.003	0.011
Gain health status VAS	-0.202	1.129	-0.203	0.688
Reduction pain VAS	0.195	1.751	0.073	0.991
Share of satisfied patients (Study III)	0.320	1.296	0.310	1.366
Level of satisfaction VAS (Study IV)	-0.008	0.016	-0.010	0.017
PROMs, six-year follow-up				
Gain EQ-5D index	0.011	0.015	0.012	0.010
Gain health status VAS	1.317	1.575	1.238	1.455
Reduction pain VAS	0.715	1.747	0.650	0.974
Level of satisfaction VAS (Study IV)	0.437	1.150	0.431	1.159

Notes: * $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$. Std. err., standard error.

6 DISCUSSION

This thesis has shown how benchmarking can be applied to assess healthcare performance with the use of register data, and contributes with different aspects and applications of performance benchmarking. First, it has provided comparisons at three levels: between countries, between regions and between departments. Second, it has demonstrated how performance measurement can be applied to both identify and analyse performance gaps, as well as to assess healthcare reforms.

In the following sections, the key findings of the empirical studies are presented and interpreted. This is followed by a discussion on the use of benchmarking and register data to assess healthcare performance. Next, strengths and limitations are highlighted. Lastly, future perspectives are reflected upon.

6.1 KEY FINDINGS AND INTERPRETATIONS

6.1.1 International comparisons

At the international level, the systematic comparisons revealed marked differences in LOS and mortality rates for hip fracture patients, both across and within included countries, after adjustment for patients' age and sex (Study I). Variations in the performance were found to be associated with the availability of national clinical guidelines, share of males in the region and country-specific effects. As expected, countries with developed and available clinical guidelines as well as regions with larger share of males performed better in terms of lower mortality rates. This indicates that there is room for improvement, and that policymakers, managers and clinicians should learn from best practices. For example, countries that have not yet introduced national clinical guidelines should perhaps do so.

There are several important factors that may further explain these differences. However, these were not possible to examine in the study. For example, different surgical methods and rehabilitation practices for various types of fractures may contribute to variations in LOS (99). Moreover, there has been efforts in the surgical and medical management of hip fracture patients which are believed to reduce mortality. These include a focus on timely surgical intervention, weight-bearing exercises earlier in the care trajectory, improved surgical devices and increased rates of discharge to non-acute healthcare facilities rather than discharge to home (100), and may further explain differences in mortality rates. In addition, pre-operative waiting time is an important factor which could affect both mortality and LOS (101, 102).

6.1.2 Regional comparisons

In Study III and Study IV, regional differences in the adoption of a reform were exploited to assess its effects on the performance of hip replacement surgery. The reform was implemented in the capital region, but not in the other Swedish regions (at least not during the study period), and involved competition and bundled payment. Together, the two studies provided a

multidimensional assessment of the reform, as several performance indicators were measured and investigated.

The main findings from these studies indicated that the reform led to the LOS of the surgical admission not decreasing at the same rate as before, and to successful reduction of the adverse event rate within 90 days following surgery (Study III). The analyses stratified by hospital type in Study III indicated that the effect on LOS was driven by lower decreases in LOS at university and central hospitals. This may be an effect of what qualitative studies have shown: a separation of low- and high-risk patients, where acute hospitals treat high-risk patients and private specialised centres treat low-risk patients (103). The decrease in the adverse event rate was also found to be specifically derived from improved rates at university and central hospitals. Furthermore, the reform brought no changes in patient satisfaction with the outcome of the surgery (Study III and Study IV) or gains in PROMs at one- and six-year follow-ups (Study IV).

Taken together, the findings from Study III and Study IV have several important implications. First, the results can be interpreted on the basis of the incentives that are embedded in the bundled payment model. Within the new model, providers are reimbursed a fixed price per patient to cover costs for all services included in the bundle, including pre-operative diagnostics, implant costs, surgery and post-operative care. Furthermore, providers are financially accountable for any complications (adverse events) within two years (up to five years in case of infections), through a complication guarantee. As part of the bundled payment, providers may also be remunerated through a performance payment of a few percentage points, if they achieve certain performance targets, such as a minimum share of patients who experience improved quality of life and pain relief one year after surgery. Compared with other payment models where providers are reimbursed for each service and thus not financially accountable for post-operative activities, providers have stronger incentives to focus on quality with the bundled payment, perhaps at the disbursement of higher resource use, such as LOS. This might explain the Study III findings of a lower decrease in LOS and reduced adverse event rate in Stockholm after the reform. Further, due to how the bundled payment was structured, the incentive for avoiding negative outcomes, such as adverse events, was stronger than that for improving PROMs, which may explain the findings of the lack of effects on PROMs in Study IV.

Second, ‘having a new hip’ is presumably the driver behind the majority of potential gains in PROMs (especially after a year, when a patient is likely to have forgotten how bad they felt at the time of surgery) and due to the bounded nature of these gains, the PROMs can only improve up to a certain limit. As the PROMs were at a relatively satisfactory level prior to the reform, it was thus perhaps not expected to see improvements in these measures. Further, had there been any minor gains, they would probably have appeared shortly after surgery.

Third, it is expected that adverse events will have a direct effect on PROMs, at least in their immediate aftermath. The seemingly contradictory finding of reduced adverse event rate, but no gains in PROMs, may also be explained by the timing discrepancy.

6.1.3 Departmental comparisons

In the productivity analysis of hip replacement surgery, differences in the development of productivity, efficiency and technology across and within orthopaedic departments were revealed (Study II). There were, however, no distinct departments that were continuously efficient and simultaneously pushing the production frontier outwards. In other words, none of the departments were identified as 'technical' leaders.

Furthermore, the overall results indicated a slight positive productivity development between 2005 and 2012. When this was decomposed, the progress was seen to primarily be due to catch-up effects, i.e., improvements in efficiency, rather than changes in technology. As previously mentioned, SHAR believes in transparency and publishes yearly reports containing performance measures from all orthopaedic departments in Sweden, with the ultimate goal to improve performance. In addition, data are to some extent accessible online through SHAR's website. With the help of these data and reports, individual departments can compare their results with others. Should a department underperform, reasons for this may be investigated and, based on that information, measures can be taken. Thus, the practice of public benchmarking may have contributed to the observed catch-up effect.

In order to improve overall productivity, variations need to be addressed and reduced by improving the performance of the least productive units.

6.2 THE USE OF BENCHMARKING AND REGISTER DATA

Benchmarking is recognised as an option in various parts of the healthcare system, including for resource funding, public reporting, administrative control, and improvement of clinical practice. Its versatility is one of the reasons why performance benchmarking is so popular (104). It is a rather straightforward process with many benefits: in its simplest form, all that is required is a means of collecting and analysing performance data, and what you get is information that enlightens decisionmaking.

The potential of healthcare registers, medical transparency and benchmarking was recognised by Codman already in the early 1900s (59, 60). Since then, Codman's 'end result system' has served as a basis for many quality improvement initiatives. What facilitates today's performance measurement is the changing attitudes in general, growing demand for health system accountability, and rapid advances in technology and analytical methodology (105), coupled with enormous amounts of routinely collected and accessible real world data. This can be contrasted with the context of a hundred years ago, when the reality was as depicted in Figure 7 (Codman's national register of bone sarcoma patients). In addition, the possibility of linking multiple registers at the level of the individual, which can be done in Sweden and many other countries, provides opportunities for further risk adjustment and multi-level analyses, where variations in performance can be disentangled at several levels (such as at the patient or provider level), which is important for fair benchmarking (7). Furthermore, the present access

to internationally comparable data creates opportunities to increase the number of observations included and thereby strengthen statistical analyses.

Figure 7. Codman's national register of bone sarcoma patients. Picture taken by Roy Mabrey. Held by Boston Medical Library in the Francis A. Countway Library of Medicine. Public Domain.

This thesis has demonstrated how benchmarking can be used at several different levels of healthcare systems to assess relative performance. In Studies I and II, performance gaps were identified between and within units of analysis (countries, regions and departments), which indicates that there is room for improvements. Further, the thesis has shown how performance measurements can be used to investigate factors which explain differences between organisations, as exemplified in Study I.

The information derived from these approaches may further be used by different stakeholders in various ways. For example, comparisons carried out at the national and international levels can provide valuable information for governments and regulators in terms of population health, regulatory effectiveness and efficiency, et cetera. Such comparisons strongly contribute to national accountability and provide important input for health policymaking (105). International level comparisons can also provide information on which national data may not be sufficient. For instance, they may lead to the discovery of more cost-effective approaches, which in turn offer useful information to a range of stakeholders, including third-party payers, regulators and providers. However, challenges connected to measurement at this level concern the availability and comparability of data, which was experienced in Study I.

On the other hand, benchmarking carried out at the hospital or departmental level, where similar services are compared, provides other relevant and useful information to care providers, among others. This may include information on, for instance, their relative performance, scope for improvement and own development. In another aspect, an advantage of assessing performance by disease or specific procedure (i.e., a disease-based approach), such as hip replacement surgery, is the possibility to relate inputs to outputs and outcomes (e.g., outcomes can be measured and linked quite accurately to costs).

From the perspective of patients, public disclosure of information about available providers and their performance enables them to make more rational choices based on personal preferences (if they can make choices). Examples of relevant information include available healthcare services, treatment options and health outcomes. In the case of elective hip replacement surgery, studies have found that patients do incorporate quality information in their choice of hospital (106, 107).

Furthermore, as demonstrated in Studies III–IV, performance measurement may also be used to evaluate healthcare policies. Such assessments provide important input that can inform policymaking. For example, the studies showed how the reform had affected various aspects of the performance of hip replacement surgery differently, possibly because of how the financial incentives were structured and linked to outcomes. From another perspective, an advantage of international data is the possibility they create by providing an appropriate control group to evaluate the effects of national healthcare policies.

In conclusion, the information derived from the different approaches and levels of benchmarking thus satisfies diverse needs among the various stakeholders in healthcare systems, which is important to consider in the design of performance measurements.

6.3 STRENGTHS AND LIMITATIONS

This thesis has contributed with a range of different aspects and applications of performance measurement. One important strength thus relates to the variety of methods which were employed to approach the study-specific objectives. In the assessment of the healthcare reform for hip replacement surgery, a quasi-experimental design was applied to estimate its causal impact on performance (Studies III–IV). The causal interpretation rests on the assumption that there are no confounding variables which cannot be accounted for. In both studies, the widely applied DiD analytical framework was employed to deal with potential time-invariant confounding caused by selection bias. In Study III, the key underlying assumption of parallel trends of the outcomes between treatment groups was considered to be fulfilled. In other words, the control group was assumed to provide an appropriate counterfactual of the trend that Stockholm would have followed in the absence of the reform, which enabled identification of treatment effects. In Study IV, data were not available to investigate this assumption. Nevertheless, to account for the differing compositions of patients between the treatment

groups, which may vary over time, weighing techniques were used in combination with DiD to reduce selection bias caused by this type of confounding.

Moreover, in Study II, where the productivity of hip replacement surgery was analysed, Malmquist productivity indices were computed, making it possible to decompose productivity changes into changes in efficiency and changes in technology. This distinction should prove useful for policy purposes, as it provides detailed information which may support managers and policymakers in undertaking actions for productivity improvement.

Another major strength of the thesis relates to the comprehensive patient level datasets that the studies were based on. The data included information on patients, procedures, resource use and quality outcomes, with the linkage between multiple registers being crucial. The data created opportunities for fair benchmarking through proper risk adjustments and provided possibilities to benchmark performance in many aspects.

Moreover, through the rich dataset on hip replacement surgeries, it was possible to evaluate the reform based on multiple performance dimensions, including aspects of resource use and both objective and subjective quality (Studies III–IV).

The studies included in the thesis are subject to a number of limitations which should be noted. First, despite the emphasis on the importance of risk adjustment for fair benchmarking, differences in patient case mix were not accounted for in the productivity analysis for hip replacement surgery in Study II, which was clearly a major limitation. In addition, Study I lacked information on aspects known to affect LOS and mortality after hip fracture, such as additional case-mix variables and pre-operative waiting time. This was largely due to differences in the availability of such information.

Second, in the assessment of the reform for hip replacement surgery (Study III and Study IV), it was not possible to separate whether the effects were driven by the introduction of patient choice, free entry of new providers through accreditation, a changed reimbursement scheme, or a combination of all of these factors. Furthermore, it is possible that the effects of the reform varied over time, however, this was not examined.

Lastly, an overall limitation of the thesis concerns costs and resource use. While Study II attempted to estimate costs, Studies I and III used LOS as means of describing resource use. However, since information on healthcare costs are not (easily) obtainable at the patient level in Sweden, and thus not linkable to patient registers, it may not be a limitation of the thesis per se. Nevertheless, from a health economic perspective, the inclusion of more accurate costs and resource use would surely have strengthened the thesis.

6.4 FUTURE PERSPECTIVES

Returning to Nutley's and Smith's (52) model of performance measurement (Figure 2), this thesis has exemplified the first two stages in the process of benchmarking: the measurement

and analysis of performance data. Differences in the performance of orthopaedic care of patients with hip fracture and osteoarthritis have been identified and disentangled at various levels of healthcare systems, indicating that there is room for improvement. Still, these performance measurements are not enough in themselves; some sort of action needs to take place for improvement to occur, as represented in the final stage of the process in Figure 2. Future perspectives should therefore focus on how this information can and should be used in practice to change organisations' behaviors in order to improve performance.

This does not apply only to the benchmarking demonstrated in the field of orthopaedic care. Although benchmarking has gained a fundamental role in many parts of healthcare systems, where management through measures is emphasised by healthcare managers and policymakers, there is limited evidence on the use of performance measures and the effects of benchmarking initiatives (6, 24, 104).

Furthermore, in its evaluation of the healthcare reform for hip replacement surgery, the thesis has contributed with important input for policymakers to consider when designing financial incentives linked to outcomes. To address relevant concerns regarding quality, policies should be preceded by a review of quality indicators in terms of the degree of poor performance and the potential for improvement. Outcomes that are at a satisfactory level should perhaps not be subject to rewards (such as the PROMs, in this case, which were unaffected by the reform). Rather, the focus should be on inferior outcomes (in this case, adverse events, which significantly decreased as an effect of the reform and led to Stockholm becoming on par with the rest of Sweden). A suggestion for future studies is to address the reform's impact on healthcare costs.

On a final note, from a health economic perspective, a register of healthcare costs, with possibilities to link to other healthcare registers at the patient level, would enable important economic analyses that could inform decisionmaking. However, this needs to be done at a national level, with costs uniformly defined and calculated in the same way across different regions.

7 CONCLUSIONS

The overall aim of this thesis was to show how benchmarking can be applied to assess healthcare performance with the use of register data. The four studies in the thesis contributed with various perspectives and measurements at different levels of healthcare systems. The information derived can satisfy diverse needs among the various stakeholders in healthcare systems, which is important to consider in the design of performance measurements.

First, the thesis has demonstrated how performance benchmarking can be applied to both identify and analyse performance gaps. At the international level, considerable variations in mortality rates and LOS in the surgical treatment of hip fractures between and within included countries were revealed. These variations were found to be associated with the availability of national clinical guidelines, the share of males in the region and country-specific effects. The findings imply that there is room for improvement, and that policymakers, healthcare managers and clinicians should learn from best practices. Study I showed that international standardised analysis of patient-level data is feasible and can be considered a step towards routine register-based international benchmarking of healthcare systems in the treatment of hip fractures.

Similarly, the departmental comparisons revealed differences in the development of productivity, efficiency and technology for hip replacement surgery across and within orthopaedic departments. The findings of a slight positive overall productivity development, due mainly to catch-up effects, may show some support for the usefulness of public reporting. To improve overall productivity, variations need to be addressed and reduced by improving the performance of the least productive units.

Second, the thesis has demonstrated how benchmarking can be beneficial in the evaluation of healthcare reforms. The effects of a regional reform involving competition and financial incentives to encourage improved performance of hip replacement surgery were analysed, where the main findings indicated that the reform led to the LOS not decreasing at the same rate as before, and to successful reduction of the adverse event rate. Moreover, the reform brought no changes in patient satisfaction or gains in PROMs at one- and six-year follow-ups. These findings contribute to the general knowledge about the effects of market elements and financial incentives and offer valuable information to various stakeholders.

Future perspectives should focus on how this information can and should be used in practice to change organisations' behavior and improve healthcare performance.

8 ACKNOWLEDGEMENTS

Becoming a PhD has been a long and challenging journey, and I would not have come this far without all the wonderful people who have been by my side during these years. For that, I am truly grateful.

My main supervisor, **Clas Rehnberg**, who is also my boss and friend (and foe, when it comes to ice hockey). And a role model within health economics. I am grateful for your trust and belief in me, and for the support along the way, especially at the end when I was having the hardest time and needed it most. Without your guidance, push forward and high thoughts about me, I doubt this thesis would have been completed. But now that it has, I can finally ask the question: what is the difference between my thesis and Linköping Hockey Club? My thesis has a title!

My co-supervisor, **Sverre A.C. Kittelsen**, for your strong support from the beginning to the end. If there is anything I need to know, I turn to you. You are my idol! Please never stop using smileys in emails, I absolutely love them! ☺

Mikko Peltola, my former co-supervisor, for your valuable thoughts and feedback, which have always been delivered in a much-needed instructive manner.

Szilárd Nemes, my former co-supervisor, for your helpful lessons about the Swedish Hip Arthroplasty Register.

My orthopaedic friends, as I call you, and co-authors, for your highly appreciated teamwork. **Göran Garellick**, my informal co-supervisor, for great support, challenges and humour along the way. **Henrik Malchau**, for showing interest in my studies when I needed it most. **Maziar Mohaddes**, for helpful, quick and effective feedback.

Many warm thanks to the **EuroHOPE study group** for all you have taught me about research and for the valuable international cooperation. A special thanks to the **co-authors of Study I**.

My sincere gratitude to my mentor **Mesfin Tessma**, for the endless encouragement and support. You are a star!

To my fellow health economists at the Centre for Health Economics, Informatics and Health Services Research, from whom I have learned so much. I am truly blessed to have such amazing colleagues and friends. The support you have given me during all these years is priceless. **Mimmi Åström**, you have been a rock to me. You are such a caring person and I appreciate our conversations about life's ups and downs. I am deeply grateful for our friendship, and of course for our morning runs. **Cecilia Dahlgren**, I do not even know where to begin to thank you. But to mention a few things I am grateful for: your never-ending positive spirit, being my training buddy (and making me run 10K and do handstands!), our invaluable feedback sessions and our great adventures in Iceland. I look forward to the day when I get my revenge in balancing-along-the-edge-the-longest-while-river-rafting. TYVM 4 ETH, IOU! **Matilda Hagman**, in the most uncomfortable situations it is you and me together. I can always count

on you, which I greatly appreciate. Many thanks for our hangouts, talks and laughs. **Sofi Varg**, thank you for being you. I love how we share the same passion for dance, knitting and Pinchos. Well, almost the same at least. **Sofia Sveréus**, you are such an incredibly smart and funny person. Your ability to understand me when not even I can is outstanding. I cherish the memories we have from traveling around the world. And to the group's latest additions: **Niklas Zethraeus** – for always being friendly, **Karoline Magnusdottir** – for your positive thoughts, and **Emelie Heintz** – you are a true inspiration. Go team Siffergasellerna!

Kristina Burström, for your valuable feedback and advice over the years, and as my mock opponent, for taking the time to prepare me for what is to come. I deeply appreciate it.

A big shout-out to the man behind the brilliant title of my thesis – **Filip Gedin**. On a more serious note, life at LIME is not the same without you. I really do appreciate our conversations about everything. Many thanks also for all the help on the home stretch!

Olivia Erntsson and **Max Kleijberg**, you rock. Hang in there – I am rooting for you!

Hilja Brorsson, for all the lessons in statistics, SAS programming and fly fishing.

Hanna Rättö, what started as an international collaboration developed into a friendship. I cannot wait for us to have a beer and catch up again!

To current and former doctoral students: **Anne Leppänen**, **Emma Granström**, **Agnes Elmberger**, **Linda Sturesson Stabel**, **Marie Dahlberg**, **Mairi Savage**, **Shaofan Chen**, **Fitsum Sebsibe Teni**, **Sara Korlén**, **Rebecca Mosson**, **Sara Ingvarsson**, **Charlotte Klinga**, **Annika Bäck**, **Shuang Hao**, **Chantelle Murley**, **Emma Spånberg** and many others. Thank you for all the fun moments we have shared.

To all my current and former colleagues at LIME, for creating a friendly work environment through support and kindness. A particular thanks to **Ebba Pettersson**, **Eva Hagel**, **Liisa Olsson**, **Vibeke Sparring**, **Marie Lind**, **Ronny Sejersen**, **Henna Hasson** and **Ulrika Schüldt Håård**.

Carl Johan Sundberg, head of LIME, your commitment to wellness is highly appreciated. **Therese Wahlström**, for the kindness and for always giving me a helping hand when needed. **Tomas Månsson**, **Gert Helgesson** and **Ingrid Smedberg** for support in the doctoral education.

For great IT support: **Erik Attoff** (and for our random conversations!), **Ludvig Andersson** and **Ludwig Berglund**.

The Swedish Hip Arthroplasty Register, for the collaboration and for providing access to the data. In particular, I want to thank **Johanna Vinblad**, **Emma Nauclér**, **Erik Bülow** and **Ola Rolfson** for their support with everything from administration to statistics.

Many warm thanks to the staff at Capio Ortopediska Huset and the patient I followed. It was a day unlike any other.

I would also like to gratefully acknowledge the financial support from the Centre for Health Economics, Informatics and Health Services Research in Region Stockholm and the European Union Seventh Framework Programme regarding the EuroHOPE project (contract no. 241721).

Many thanks to the various constellations at LIME of which I am part: **LIME running club** – because you make me move, **Creative lunches** – for very nice company and knitting lessons, and **Kappa-gruppen** – for incredible support during the coronavirus pandemic and the final year of my PhD studies.

A special thanks also to **Shakira** and **Wyclef Jean** for the catchy song! Who could have guessed that a PhD thesis would be named after it?!

Mina närmaste vänner: **Maria Nymark**, **Sara Henning**, **Maria Wallard** och **Jennifer Brännerud**. Jag saknar er och längtar tills vi kan umgås normalt igen.

Min älskade familj, som är den absolut bästa man kan ha. Tack för att ni alltid finns där.

Mamma och **pappa**, för allt ni har lärt mig om livet och för att ni alltid tror på mig. Det är er omtanke och kärlek som har format mig. **Eva**, jag är så glad att just du kom in i pappas och våra liv.

Mina systrar, **Anna** och **Malin**, som också är mina bästa vänner. Jag får ofta höra från andra om hur speciellt vårt band är och att vi delar så mycket i livet med varandra. Och just det är jag så tacksam för – för allt vi delar. Tänk vad lyckligt lottad jag är som inte bara fick en, utan två helt fantastiska systrar.

Världens finaste påg, min systerson **Oliver**. Det är en fröjd att se dig växa upp.

Familjen Blad, min skånska familj. Tack för alla fantastiska äventyr ni tar med mig på. **Lotten**, det är lite tveksamt om detta räcker till en Nobelfest, men som tur är har vi ju andra trevligheter att se fram emot!

Anders, min hjärtevän och alldeles egna stöttepelare i livet. Vad skulle jag göra utan dig? Med dig har jag aldrig tråkigt och tillsammans kan vi vara konstiga. Jag ser fram emot våra framtida äventyr. Ik hou van jou. ♥ ♥ ♥


TO BE OR NOT TO BE A REGISTRY NERD
– THAT IS THE QUESTION!
©Swedish Hip Arthroplasty Register

9 REFERENCES

1. Jack W, Lewis M. Health Investments And Economic Growth: Macroeconomic Evidence And Microeconomic Foundations. *Policy Research Working Papers*. 2009.

2. Hollingsworth B. Cost, production, efficiency, or effectiveness: where should we focus? *The Lancet Global Health*. 2013;1(5):e249-e250.

3. Hurst J, Jee-Hughes M. Performance Measurement and Performance Management in OECD Health Systems. *OECD Labour Market and Social Policy Occasional Papers*. 2001.

4. Peiró S, Maynard A. Variations in health care delivery within the European Union. *European Journal of Public Health*. 2015;25 Suppl 1:1-2.

5. Van Helden GJ, Tillema S. In search of a benchmarking theory for the public sector. *Financial Accountability and Management*. 2005;21(3):337-361.

6. Kay JFL. Health care benchmarking. *Hong Kong Medical Diary*. 2007;12(2):22-27.

7. Cnudde P, Rolfson O, Nemes S, Kärrholm J, Rehnberg C, Rogmark C, et al. Linking Swedish health data registers to establish a research database and a shared decision-making tool in hip replacement. *BMC Musculoskeletal Disorders*. 2016;17(1):414.

8. OECD. Measuring up: Lessons and Potential. 2003. In: *Measuring Up: Improving Health System Performance in OECD Countries* [Internet]. OECD Publishing. Available from: https://www.oecd-ilibrary.org/content/component/9789264195950-18-en.

9. Institute of Medicine (US) Committee to Design a Strategy for Quality Review and Assurance in Medicare. 1, Health, Health Care, and Quality of Care. 1990. In: *Medicare: A Strategy for Quality Assurance* [Internet]. Lohr KN, editor. Washington (DC): National Academies Press (US). Available from: https://www.ncbi.nlm.nih.gov/books/NBK235460/.

10. Thomas JW, Guire KE, Horvat GG. Is patient length of stay related to quality of care? *Journal of Healthcare Management*. 1997;42(4):489.

11. Sund R, Gissler M, Hakulinen T, Rosén M. Use of Health Registers. In: *Handbook of Epidemiology*. Ahrens W, Pigeot I, editors. New York, NY: Springer New York; 2014. p. 707-730.

12. National Quality Registries. About the National Quality Registries [Internet]. [2021-03-15]. Available from: https://kvalitetsregister.se/englishpages/aboutqualityregistries.2422.html.

13. Crimmins EM. Lifespan and Healthspan: Past, Present, and Promise. *The Gerontologist*. 2015;55(6):901-911.

14. Institute of Medicine (US) Committee on Quality of Health Care in America. Appendix A, Report of the Technical Panel on the State of Quality to the Quality of Health Care in America Committee. 2001. In: *Crossing the Quality Chasm: A New Health System for the 21st Century* [Internet]. Washington (DC): National Academies Press (US). Available from: https://www.ncbi.nlm.nih.gov/books/NBK222263/.

15. Hicks CW, Makary MA. A prophet to modern medicine: Ernest Amory Codman. *BMJ*. 2013;347.

16. Linna M, Häkkinen U, Magnussen J. Comparing hospital cost efficiency between Norway and Finland. *Health Policy*. 2006;77(3):268-278.

17. Smith PC. Measuring health system performance. *The European Journal of Health Economics*. 2002;3(3):145-148.

18. Smith P, Mossialos E, Papanicolas I, Leatherman S. Principles of performance measurement. In: *Performance Measurement for Health System Improvement: Experiences, Challenges and Prospects.* Smith P, Mossialos E, Papanicolas I, Leatherman S, editors. Cambridge: Cambridge University Press; 2009.

19. Gaynor M, Vogt WB. Antitrust and competition in health care markets. In: *Handbook of Health Economics.* Elsevier; 2000. p. 1405-1487.

20. Song PH, Barlow JD, Seiber EE, McAlearney AS. Competition in Health Care. In: *International Encyclopedia of Public Health.* Quah SR, editor. Second ed. Oxford: Academic Press; 2017. p. 129-133.

21. Gaynor M, Haas-Wilson D. Change, Consolidation, and Competition in Health Care Markets. *Journal of Economic Perspectives*. 1999;13(1):141-164.

22. Arrow KJ. Uncertainty and the Welfare Economics of Medical Care. *The American Economic Review*. 1963;53(5):941-973.

23. Van de Ven WP, Schut FT, Rutten FF. Forming and reforming the market for third-party purchasing of health care. *Social Science and Medicine*. 1994;39(10):1405-1412.

24. Mannion R, Goddard M. Performance measurement and improvement in health care. *Applied health economics and health policy*. 2002;1(1):13-23.

25. Ochrana F, Plaček M, Půček M. Benchmarking as a substitute for the market mechanism: Empirical evidence for the Czech Republic. *Procedia Economics and Finance*. 2015;30:606-612.

26. Moriarty JP, Smallman C. En route to a theory of benchmarking. *Benchmarking: An International Journal*. 2009;16(4):484-503.

27. Van de Ven WP. Market-oriented health care reforms: Trends and future options. *Social Science and Medicine*. 1996;43(5):655-666.

28. Le Grand J. Choice and competition in publicly funded health care. *Health Economics, Policy and Law*. 2009;4(4):479-488.

29. Propper C. Competition, incentives and the English NHS. *Health Economics.* 2012;21(1):33-40.

30. Vrangbaek K, Robertson R, Winblad U, Van de Bovenkamp H, Dixon A. Choice policies in Northern European health systems. *Health Economics, Policy, and Law*. 2012;7(1):47-71.

31. Dahlgren G. Why public health services? Experiences from profit-driven health care reforms in Sweden. *International journal of health services: planning, administration, evaluation*. 2014;44(3):507-524.

32. Anell A. The Public–Private Pendulum — Patient Choice and Equity in Sweden. *The New England journal of medicine*. 2015;372(1):1-4.

33. Eijkenaar F. Pay for Performance in Health Care: An International Overview of Initiatives. *Medical Care Research and Review*. 2012;69(3):251-276.

34. Saltman RB. Regulating incentives: the past and present role of the state in health care systems. *Social Science and Medicine*. 2002;54(11):1677-1684.

35. Ma C-tA. Health Care Payment Systems: Cost and Quality Incentives. *Journal of Economics & Management Strategy*. 1994;3(1):93-112.

36. Barnum H, Kutzin J, Saxenian H. Incentives and provider payment methods. *The International journal of health planning and management*. 1995;10(1):23-45.

37. Propper C, Wilson D, Burgess S. Extending Choice in English Health Care: The Implications of the Economic Evidence. *Journal of Social Policy*. 2006;35(4):537-557.

38. Barros PP, Brouwer WBF, Thomson S, Varkevisser M. Competition among health care providers: helpful or harmful? *The European journal of health economics*. 2016;17(3):229-233.

39. Anell A. Hälso- och sjukvårdstjänster i privat regi [Privately provided healthcare services]. In: *Konkurrensens konsekvenser - Vad händer med svensk välfärd?* Hartman L, editor. Studieförbundet Näringsliv och samhälle; 2011.

40. Gaynor M, Town RJ. Competition in health care markets. In: *Handbook of health economics.* Elsevier; 2011. p. 499-637.

41. Fotaki M. Is Patient Choice the Future of Health Care Systems? *International Journal of Health Policy and Management.* 2013;1(2):121-123.

42. Fotaki M, Roland M, Boyd A, McDonald R, Scheaff R, Smith L. What benefits will choice bring to patients? Literature review and assessment of implications. *Journal of health services research & policy*. 2008;13(3):178-184.

43. Chaix-Couturier C, Durand-Zaleski I, Jolly D, Durieux P. Effects of financial incentives on medical practice: results from a systematic review of the literature and methodological issues. *International journal for quality in health care*. 2000;12(2):133-142.

44. Eijkenaar F, Emmert M, Scheppach M, Schöffski O. Effects of pay for performance in health care: a systematic review of systematic reviews. *Health Policy*. 2013;110(2-3):115-130.

45. Flodgren G, Eccles MP, Shepperd S, Scott A, Parmelli E, Beyer FR. An overview of reviews evaluating the effectiveness of financial incentives in changing healthcare professional behaviours and patient outcomes. *The Cochrane database of systematic reviews*. 2011(7):Cd009255.

46. Scott A, Sivey P, Ait Ouakrim D, Willenberg L, Naccarella L, Furler J, et al. The effect of financial incentives on the quality of health care provided by primary care physicians. *The Cochrane database of systematic reviews*. 2011(9):Cd008451.

47. Lindenauer PK, Remus D, Roman S, Rothberg MB, Benjamin EM, Ma A, et al. Public reporting and pay for performance in hospital quality improvement. *The New England journal of medicine*. 2007;356(5):486-496.

48. Berwick DM, James B, Coye MJ. Connections between quality measurement and improvement. *Medical care*. 2003:I30-I38.

49. Shekelle PG. Public performance reporting on quality information. In: *Performance Measurement for Health System Improvement: Experiences, Challenges and Prospects.* Smith P, Mossialos E, Papanicolas I, Leatherman S, editors. Cambridge: Cambridge University Press; 2009.

50. Conrad DA. Incentives for health-care performance improvement. In: *Performance Measurement for Health System Improvement: Experiences, Challenges and Prospects.*

Smith P, Mossialos E, Papanicolas I, Leatherman S, editors. Cambridge: Cambridge University Press; 2009.

51. World Health Organization. The world health report 2000: health systems: improving performance. World Health Organization; 2000.

52. Nutley S, Smith PC. League tables for performance improvement in health care. *Journal of health services research & policy*. 1998;3(1):50-57.

53. Ettorchi-Tardy A, Levif M, Michel P. Benchmarking: a method for continuous quality improvement in health. *Healthcare policy*. 2012;7(4):e101-e119.

54. Loeb JM. The current state of performance measurement in health care. *International journal for quality in health care*. 2004;16 Suppl 1:i5-9.

55. McIntyre D, Rogers L, Heier EJ. Overview, History, and Objectives of Performance Measurement. *Health care financing review*. 2001;22(3):7-21.

56. Percival T. *Medical Ethics: or, a code of institutes and precepts adapted to the professional conduct of physicians and surgeons. To which is added an appendix containing a discourse on hospital duties [by TB Percival]; also notes and illustrations*: S. Russell; 1803.

57. Varghese TK. A Legacy of Surgical Outcomes [Internet]. [2021-02-17]. Available from: https://hcldr.wordpress.com/2014/04/20/a-legacy-of-surgical-outcomes/.

58. Pellegrino ED. Percival's Medical Ethics: The Moral Philosophy of an 18th-Century English Gentleman. *Archives of Internal Medicine*. 1986;146(11):2265-2269.

59. Codman EA. *A study in hospital efficiency: as demonstrated by the case report of the first five years of a private hospital*. 1917.

60. Brand RA. Ernest Amory Codman, MD, 1869-1940. *Clinical orthopaedics and related research*. 2009;467(11):2763-2765.

61. Mueller K. Commentary: Ernest Codman and the Impact of Quality Improvement in Neurosurgery: A Century Since the Idea of the “End Result”. *Neurosurgery*. 2018;84(2):E116-E119.

62. Thonon F, Watson J, Saghatchian M. Benchmarking facilities providing care: An international overview of initiatives. *SAGE open medicine*. 2015;3.

63. Wait S, Nolte E. Benchmarking health systems: trends, conceptual issues and future perspectives. *Benchmarking: an international journal*. 2005;12(5):436-448.

64. OECD. Health Statistics [Internet]. [2021-03-15]. Available from: https://www.oecd.org/health/health-statistics.htm.

65. Registercentrum Västra Götaland. About National Quality Registers [Om nationella kvalitetsregister] [Internet]. [2021-03-15]. Available from: https://registercentrum.se/om-oss/om-nationella-kvalitetsregister/p/rk21maUUf.

66. Swedish Association of Local Authorities and Regions. Regional Comparisons: healthcare [Öppna jämförelser: hälso- och sjukvård] [Internet]. [2021-03-15]. Available from: https://skr.se/tjanster/merfranskl/oppnajamforelser/halsoochsjukvard.1563.html.

67. National Board of Health and Welfare. Regional Comparisons [Öppna Jämförelser] [Internet]. [2021-03-15]. Available from: https://www.socialstyrelsen.se/statistik-och-data/oppna-jamforelser/.

68. Campbell SM, Braspenning J, Hutchinson A, Marshall M. Research methods used in developing and applying quality indicators in primary care. *Quality & safety in health care*. 2002;11(4):358-364.

69. Häkkinen U, Iversen T, Peltola M, Seppälä TT, Malmivaara A, Belicza É, et al. Health care performance comparison using a disease-based approach: The EuroHOPE project. *Health Policy*. 2013;112(1):100-109.

70. Heijink R, Engelfriet P, Rehnberg C, Kittelsen SAC, Häkkinen U. A Window on Geographic Variation in Health Care: Insights from EuroHOPE. *Health Economics*. 2015;24(S2):164-177.

71. Häkkinen U, Iversen T, Peltola M, Rehnberg C, Seppälä TT, group obotEs. Towards Explaining International Differences in Health Care Performance: Results of the EuroHOPE Project. *Health Economics*. 2015;24(S2):1-4.

72. Swedish Hip Arthroplasty Register. Annual Report 2019. Swedish Hip Arthroplasty Register; 2020.

73. Cooper C, Cole ZA, Holroyd CR, Earl SC, Harvey NC, Dennison EM, et al. Secular trends in the incidence of hip and other osteoporotic fractures. *Osteoporosis international*. 2011;22(5):1277-1288.

74. Cooper C, Campion G, Melton LJ. Hip fractures in the elderly: a world-wide projection. *Osteoporosis international* 1992;2(6):285-289.

75. Nemes S, Gordon M, Rogmark C, Rolfson O. Projections of total hip replacement in Sweden from 2013 to 2030. *Acta Orthopaedica*. 2014;85(3):238-243.

76. Hälso- och sjukvårdsnämndens förvaltning - Stockholms Läns Landsting. Regelbok för höft- och knäprotesoperationer, 2011 [Rulebook for hip and knee replacement operations, 2011]. Region Stockholm; 2011.

77. Swedish Association of Local Authorities and Regions. KPP Databas [Cost per patient database] [Internet]. [2021-03-15]. Available from: https://skr.se/skr/halsasjukvard/kunskapsstodvardochbehandling/kostnadperpatientkpp/kppdatabas.46722.html.

78. Färe R, Grosskopf S, Lindgren B, Roos P. Productivity changes in Swedish pharamacies 1980–1989: A non-parametric Malmquist approach. *Journal of Productivity Analysis*. 1992;3(1):85-101.

79. Färe R, Grifell-Tatjé E, Grosskopf S, Knox Lovell CA. Biased Technical Change and the Malmquist Productivity Index. *Scandinavian journal of Economics*. 1997;99(1):119-127.

80. Färe R, Grosskopf S, Roos P. Produktivitetsutvecklingen inom sjukhussektorn 1970-1992 [Productivity growth in the hospital sector 1970-1992]. Finansdepartementet (Ministry of Finance); 1994.

81. Simar L, Wilson P. Estimating and bootstrapping Malmquist indices. *European journal of operational research*. 1999;115(3):459-471.

82. Simar L, Wilson P. A general methodology for bootstrapping in non-parametric frontier models. *Journal of applied statistics*. 2000;27(6):779-802.

83. Wilson P. FEAR: A software package for frontier efficiency analysis with R. *Socio-economic planning sciences*. 2008;42(4):247-254.

84. Angrist JD, Pischke J-S. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton: Princeton University Press; 2008.

85. Dimick JB, Ryan AM. Methods for Evaluating Changes in Health Care Policy: The Difference-in-Differences Approach. *JAMA*. 2014;312(22):2401-2402.

86. Lechner M. The Estimation of Causal Effects by Difference-in-Difference Methods. *Foundations and Trends in Econometrics*. 2011;4(3):165-224.

87. Wing C, Simon K, Bello-Gomez RA. Designing Difference in Difference Studies: Best Practices for Public Health Policy Research. *Annual review of public health*. 2018;39(1):453-469.

88. Bertrand M, Duflo E, Mullainathan S. How Much Should We Trust Differences-In-Differences Estimates? *The Quarterly Journal of Economics*. 2004;119(1):249-275.

89. SAS. Version 9.4. 2003.

90. Stuart EA, Huskamp HA, Duckworth K, Simmons J, Song Z, Chernew M, et al. Using propensity scores in difference-in-differences models to estimate the effects of a policy change. *Health Services and Outcomes Research Methodology*. 2014;14(4):166-182.

91. Hainmueller J. Entropy Balancing for Causal Effects: A Multivariate Reweighting Method to Produce Balanced Samples in Observational Studies. *Political Analysis*. 2012;20(1):25-46.

92. Faries D, Zhang X, Kadziola Z, Siebert U, Kuehne F, Obenchain RL, et al. *Real World Health Care Data Analysis: Causal Methods and Implementation Using SAS*. SAS Institute; 2020.

93. Blundell R, Dias MC. Alternative Approaches to Evaluation in Empirical Microeconomics. *Journal of Human Resources*. 2009;44(3):565-640.

94. Achelrod D, Welte T, Schreyögg J, Stargardt T. Costs and outcomes of the German disease management programme (DMP) for chronic obstructive pulmonary disease (COPD)-A large population-based cohort study. *Health Policy*. 2016;120(9):1029-1039.

95. Austin PC. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. *Multivariate behavioral research*. 2011;46(3):399-424.

96. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013;310(20):2191-2194.

97. Ludvigsson JF, Håberg SE, Knudsen GP, Lafolie P, Zoega H, Sarkkola C, et al. Ethical aspects of registry-based research in the Nordic countries. *Clinical epidemiology*. 2015;7:491-508.

98. Patientdatalag (2008:355) [Patient Data Act], 2008.

99. Sund R, Riihimäki J, Mäkelä M, Vehtari A, Lüthje P, Huusko T, et al. Modeling the length of the care episode after hip fracture: does the type of fracture matter? *Scandinavian Journal of Surgery*. 2009;98(3):169-174.

100. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and Mortality of Hip Fractures in the United States. *JAMA*. 2009;302(14):1573-1579.

101. Sund R, Liski A. Quality effects of operative delay on mortality in hip fracture treatment. *BMJ Quality & Safety*. 2005;14(5):371-377.

102. Siegmeth AW, Gurusamy K, Parker MJ. Delay to surgery prolongs hospital stay in patients with fractures of the proximal femur. *The Journal of bone and joint surgery - British volume*. 2005;87(8):1123-1126.

103. Korlén S, Amer-Wåhlin I, Lindgren P, von Thiele Schwarz U. Professionals' perspectives on a market-inspired policy reform: A guiding light to the blind spots of measurement. *Health Services Management Research*. 2017;30(3):148-155.

104. Elg M, Broryd KP, Kollberg B. Performance measurement to drive improvements in healthcare practice. *International Journal of Operations & Production Management*. 2013.

105. Smith P, Mossialos E, Papanicolas I, Leatherman S. Conclusions. In: *Performance Measurement for Health System Improvement: Experiences, Challenges and Prospects.* Smith P, Mossialos E, Papanicolas I, Leatherman S, editors. Cambridge: Cambridge University Press; 2009.

106. Beukers PD, Kemp RG, Varkevisser M. Patient hospital choice for hip replacement: empirical evidence from the Netherlands. *The European Journal of Health Economics*. 2014;15(9):927-936.

107. Gutacker N, Siciliani L, Moscelli G, Gravelle H. Choice of hospital: Which type of quality matters? *Journal of Health Economics*. 2016;50:230-246.

10 APPENDIX

10.1 APPENDIX A – QUESTIONNAIRE ON REIMBURSEMENT SCHEME

Enkät: Ersättning höftprotesoperationer

Vänligen fyll i blåmarkerade rutor enligt anvisning.

Region:

Vänligen fyll i uppgifterna nedan med hjälp av förkortningarna för respektive år.

Hur sker ersättningen av höftprotesoperationer, uppdelat på akutsjukhus och övriga vårdgivare (privata), i er region?

	Akutsjukhus	Övriga vårdgivare (privata)	*Ev. kommentar*
1999			
2000			
2001			
2002			
2003			
2004			
2005			
2006			
2007			
2008			
2009			
2010			
2011			
2012			
2013			
2014			
2015			
2016			
2017			
2018			
2019			

Olika typer av ersättningar och deras förkortningar:

B = Budget/anslag

DRG = Ersättning per produktgrupp baserad på DRG

V = Vårdepisodersättning (bundled payment) inkl. vård för komplikationer efter utskrivning

Å = Åtgärdsbaserad ersättning

Ö = Övrigt, specificera i kommentar

10.2 APPENDIX B – CHANGES IN EFFICIENCY

Department	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
1	0.816	1.120*	1.045	1.048	1.000	1.000	0.963
2	1.095*	1.022	0.978	0.910*	1.091*	0.926*	0.998
3	1.191*	0.883*	1.028	0.937*	0.927*	0.981	0.996
4	1.174*	0.958*	0.966*	0.943	1.034	1.045*	0.944*
5	1.086*	0.987	1.060	0.979	0.990	0.988	0.950*
6	1.034*	1.026	1.031	0.933*	0.980	1.052*	0.953*
7	1.157*	1.046*	0.991	1.005	1.071	1.033	0.960
8	1.116*	1.000	1.000	1.000	1.000	1.000	0.989
9	1.135	1.000	1.000	1.000	1.000	1.000	1.000
10	1.034	1.168*	0.929*	0.980	1.007	0.997	0.948*
11	1.124*	0.916*	0.886*	1.030	1.002	1.115*	1.005
12	1.132*	0.987	0.988	0.763*	1.116*	1.083*	0.966
13	1.007	1.080*	0.959*	0.969	0.957	1.130*	0.974
14	1.035	1.001	0.993	1.007	1.000	1.000	0.988
15	1.181*	1.033	0.978	0.893*	0.996	0.961	1.042
16	1.080*	0.953	0.983	0.998	1.143*	1.065*	0.945*
17	1.112*	0.989	0.990	0.999	1.136*	1.148*	0.883*
18	1.242*	0.995	1.012	0.961*	1.022	1.002	1.064*
19	0.935*	1.091	1.018	0.995	0.995	1.058*	0.997
20	1.143*	0.950*	1.017	0.963*	1.012	1.043*	1.064*
21	1.057	1.111*	1.096*	0.923*	0.935*	1.056*	0.976
22	1.082*	1.048*	0.911*	0.956*	1.031	1.183*	1.043
23	1.107*	0.928*	1.070*	1.042	0.996	1.060*	0.935*
24	1.197*	1.002	1.022	0.933*	1.008	0.911*	0.922
25	1.000	1.000	1.000	1.000	0.962	1.027	1.012
26	1.072	1.000	1.000	1.000	1.000	1.000	0.966
27	0.950	1.140*	1.099*	0.864*	0.962	1.029*	0.972*
28	1.053	1.011	1.028	0.891	0.995	0.985	1.030
29	1.092*	1.087*	1.005	0.866*	0.953	0.984	1.034
30	1.193*	0.921*	1.001	0.943*	1.106*	0.963	1.125*
31	1.195*	0.940*	1.046*	0.853*	1.043*	1.033*	0.945*
32	0.843	1.138*	0.945*	1.014	1.086	0.949	1.042
33	1.043	0.944*	1.058*	0.927*	1.179*	0.965	1.100*
34	1.088*	1.068*	0.980	0.891*	0.968	1.061*	0.996
35	1.010	0.990	1.020	1.025	1.000	1.000	1.000
36	1.190	0.789	1.057*	0.982	1.082*	1.070*	0.913*
37	1.114*	0.961*	1.085*	0.914*	0.985	0.928	0.952
38	1.055*	1.051*	0.976	1.027	0.939*	1.078*	0.893*
39	1.000	1.000	1.000	1.000	0.989	1.012	1.000
40	1.222*	1.033	0.961	0.935*	1.032	1.121*	1.000
41	1.110*	0.948*	1.098*	0.951*	1.012	1.027	1.004
42	0.982	1.105*	0.919*	0.952	1.216*	0.984	0.997
43	0.992	1.226*	0.711*	1.065*	1.028	1.170*	1.039*
44	0.915*	1.034	0.953	0.868*	1.228*	1.013	1.026
45	1.047	0.962	0.970	1.051*	1.010	1.089*	1.079*

Department	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
46	1.172*	0.965*	1.051*	0.879*	0.976	1.013	1.017
47	1.093*	1.011	1.035	1.022	0.920	1.091*	1.035
48	1.094*	1.049*	0.908*	0.977	0.983	1.099*	0.994
49	1.144*	1.014	1.050*	0.940*	0.940	0.976	0.928
50	1.287*	0.998	0.877*	1.050	0.996	1.004	0.971
51	1.045	1.047*	0.970	1.071*	1.017	0.991	0.964
52	1.142*	0.997	1.016	0.928*	1.000	0.974	1.016
53	1.107*	1.013	1.040	0.912*	1.010	1.015	1.012
54	1.092*	1.060*	0.923*	0.911*	0.984	1.086*	0.929*
55	1.152*	0.941*	0.962	0.879*	1.046*	0.987	1.007
56	1.200*	0.875	1.135	0.952	1.045*	1.046	1.000
57	1.176*	0.967	1.091*	1.039	1.163*	0.995	0.995
58	1.045*	1.044	0.876*	1.195*	0.896*	1.075*	0.903*
59	1.111*	0.936	0.972	0.974	1.053*	1.057*	0.943*
60	1.145*	1.052*	0.927*	0.848*	1.113*	1.075*	1.053*
61	1.029	0.974	1.053	1.164	1.000	1.000	1.000
62	1.137*	0.981*	1.005	0.971*	0.972	0.920*	1.037*
63	1.068*	1.006	1.042*	0.906*	0.990	1.056*	0.956
64	1.132*	0.967*	1.048*	0.907*	1.020	0.957*	0.942
65	1.080*	0.998	1.071*	0.941*	0.954	1.074*	0.973
Geometric mean	1.087*	1.006*	0.996*	0.961*	1.018*	1.026*	0.988*

Notes: The numbers show annual change in efficiency between two consecutive years, = 1 indicates no change, > 1 indicates progress, < 1 indicates regress. * indicates statistically significantly different from 1.0 at 95% level.

10.3 APPENDIX C – CHANGES IN TECHNOLOGY

Department	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
1	1.116	0.844*	0.885*	1.073*	1.120*	0.993	0.977
2	1.124*	0.840*	0.869*	1.104*	1.116*	0.999	0.994
3	1.092*	0.860*	0.889*	1.037*	1.126*	0.993	0.993
4	1.114*	0.853*	0.877*	1.009	1.072*	0.971*	1.017
5	1.217*	0.899*	0.926	0.992	1.052	0.990	1.002
6	1.167*	0.874*	0.908*	1.008	1.082*	0.983	1.014
7	1.184*	0.829*	0.880*	1.030	1.094*	1.004	0.973
8	1.218*	0.874*	0.971	0.969	1.106*	0.971	0.984
9	1.191	1.047	0.988	0.965	1.086	0.929	1.013
10	1.218*	0.810*	0.879*	1.026	1.102*	1.000	0.989
11	1.118*	0.868*	0.968	0.979	1.099*	0.977	0.979
12	1.199*	0.883*	0.913*	1.059*	1.101*	0.988	1.002
13	1.187*	0.816*	0.883*	1.053*	1.126*	0.993	0.990
14	1.172*	1.045	0.869*	1.031	1.023	0.979	1.015
15	1.115*	0.866*	0.893*	1.051*	1.136*	1.011	0.975
16	1.239*	0.936*	0.921	0.971	1.058	0.964*	1.013
17	1.237*	0.898*	0.939	0.988	1.050	0.967	1.015
18	1.098*	0.866*	0.885*	1.080*	1.144*	1.031	0.984
19	1.138*	0.867*	0.903*	0.981	1.058	0.948*	0.997
20	1.097*	0.858*	0.896*	1.061*	1.091*	0.992	1.009
21	1.211*	0.816*	0.870*	1.078*	1.133*	0.982	0.980
22	1.143*	0.856*	0.901*	1.052*	1.116*	0.997	0.991
23	1.151*	0.868*	0.903*	1.043*	1.096*	0.986	0.997
24	1.092*	0.866*	0.885*	1.080*	1.144*	1.031	0.961
25	1.190*	0.850*	0.925*	0.974	1.056	0.985	1.019
26	1.215	1.057	0.767*	1.051	0.994	1.017	0.971
27	1.215*	0.887*	0.899*	0.992	1.039	0.960*	1.016
28	1.208*	0.897*	0.895	0.985	1.072*	0.974	0.984
29	1.101*	0.861*	0.884*	1.102*	1.122*	1.017	0.982
30	1.101*	0.858*	0.881*	1.094*	1.133*	1.019	1.009
31	1.104*	0.856*	0.882*	1.079*	1.102*	0.994	1.008
32	1.156	0.905*	0.914	1.018	1.041	0.963	0.997
33	1.181*	0.854*	0.876*	1.035*	1.094*	0.998	0.991
34	1.092*	0.866*	0.886*	1.100*	1.109*	1.005	1.000
35	1.176*	0.889*	0.930*	1.032	1.123*	1.024	0.982
36	1.419*	0.865*	0.892*	1.047*	1.106*	0.993	0.993
37	1.092*	0.862*	0.878*	1.057*	1.102*	0.993	0.994
38	1.218*	0.881*	0.968	0.967	1.102*	0.973	0.975
39	1.186*	0.859*	0.888*	1.026	1.090*	1.009	0.965
40	1.160*	0.852*	0.896*	1.059*	1.118*	1.002	0.993
41	1.217*	0.877*	0.874*	1.075*	1.114*	0.999	0.987
42	1.188*	0.916*	0.927	1.038	1.049	0.947*	1.015
43	1.271*	0.996	0.924	0.981	1.066*	0.972*	0.998
44	1.207*	0.892*	0.944	0.985	1.057	0.964*	1.003
45	1.265*	0.890*	0.940	0.959	1.060	0.982	1.008

Department	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
46	1.115*	0.849*	0.875*	1.052*	1.097*	0.994	0.998
47	1.186*	0.884*	0.930	0.988	1.051	0.961*	1.014
48	1.216*	0.820*	0.874*	1.060*	1.124*	0.986	0.986
49	1.092*	0.866*	0.885*	1.080*	1.144*	1.031	0.979
50	1.229*	0.887*	0.916*	1.016	1.081*	0.976	0.991
51	1.249*	0.843*	0.886*	0.983	1.071*	0.996	0.991
52	1.165*	0.854*	0.887*	1.074*	1.124*	1.010	0.983
53	1.116*	0.828*	0.876*	1.037	1.107*	0.995	0.986
54	1.210*	0.817*	0.877*	1.003	1.061	0.974	1.020
55	1.103*	0.858*	0.905*	1.038*	1.082*	0.983	0.998
56	1.167	0.936	0.889	1.012	1.030	1.007	1.009
57	1.200*	0.908*	0.926	1.006	1.041	0.972	0.997
58	1.111*	0.836*	0.878*	1.008	1.076*	1.000	0.990
59	1.209*	0.902*	0.964	0.971	1.044	0.965	1.024
60	1.173*	0.852*	0.883*	1.087*	1.105*	1.002	0.990
61	1.243*	0.849*	0.878*	1.004	1.146	1.054	0.986
62	1.095*	0.858*	0.893*	1.072*	1.116*	1.008	0.992
63	1.145*	0.833*	0.870*	1.073*	1.112*	0.995	0.997
64	1.092*	0.859*	0.885*	1.093*	1.115*	1.012	1.000
65	1.138*	0.825*	0.871*	1.103*	1.121*	0.997	0.993
Geometric mean	1.169*	0.874*	0.898*	1.032*	1.091*	0.990*	0.995*

Notes: The numbers show annual change in technology between two consecutive years, = 1 indicates no change, > 1 indicates progress, < 1 indicates regress. * indicates statistically significantly different from 1.0 at 95% level.